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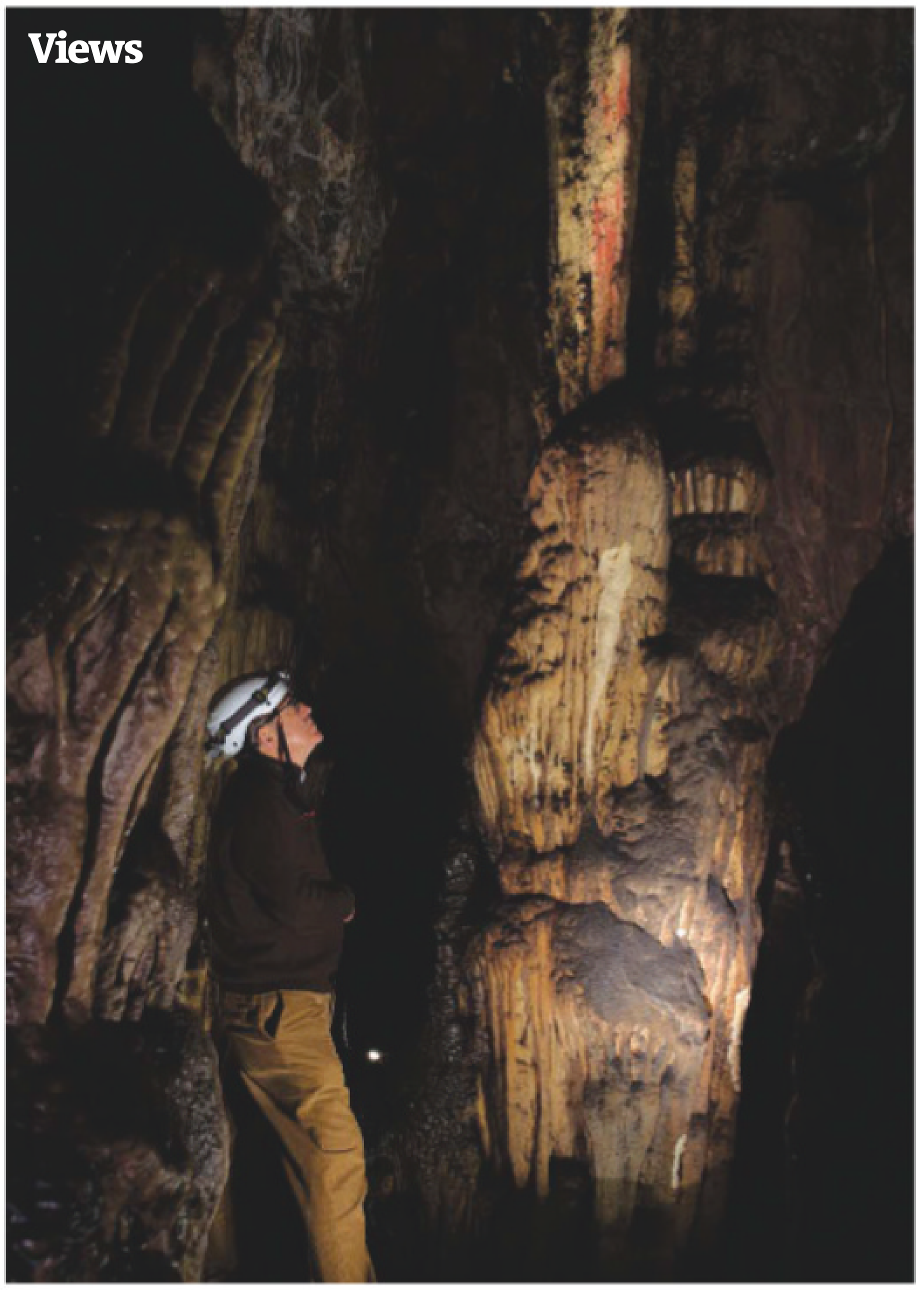

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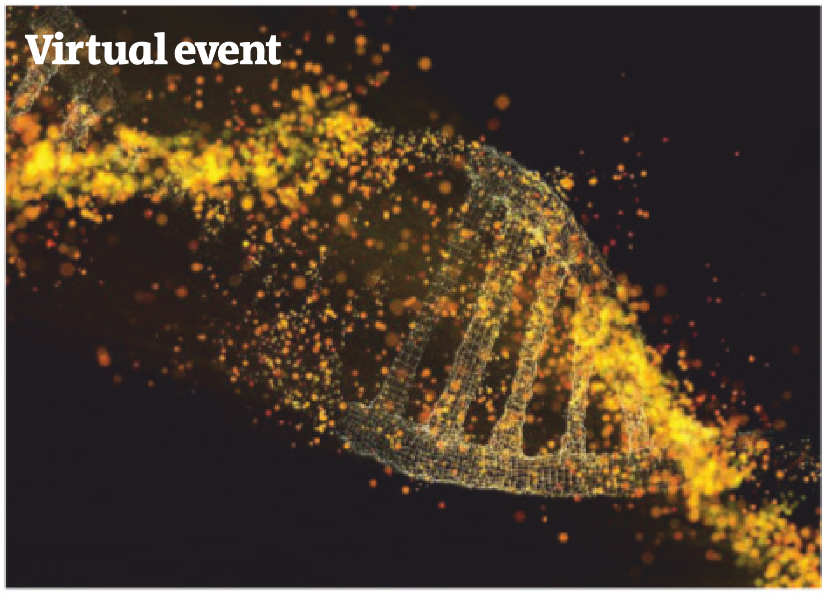

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Covid-19 vaccine Once it is developed, who will get it first?

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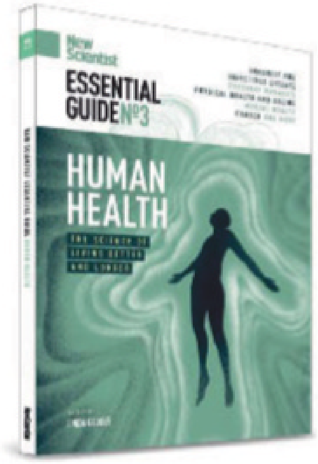

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All that glitters...

It is time to do away with flashy science and outlandish claims

ONE of the special things about science is its inbuilt system of self-correction. There is no such thing as scientific truth, just a set of provisional truths that are subject to revision or rejection when new information comes in. That process isn't always quick or peaceful, but it usually gets to an answer in the end. The result is scientific progress.

Today, science badly needs to turn that commitment to self-correction on its own processes. Science involves many exciting discoveries, but not all incremental advances can be revolutionary. In a bid to get pulses racing with newsworthy findings, scientists are throwing caution to the wind. As psychologist Stuart Ritchie explains on page 36, the values that make science so successful – universalism, disinterestedness, organised scepticism and common ownership of knowledge – are being sacrificed on the altar of hyperbole.

The problem is one of perverse incentives. Almost everyone in the science ecosystem benefits from flashy original discoveries and astounding claims: the scientists, their institutions, grant-awarding bodies, academic journals, press officers and the media. Almost nobody benefits from caution, such as diligently combing through other people's data or replicating experiments. As a result, science is increasingly and worryingly unreliable.

> "The values that make science so successful are being sacrificed on the altar of hyperbole"

Similar criticisms have circulated for years, but when science is probably our best tool in tackling the coronavirus pandemic, it is more important than ever to make sure it is done well.

Fortunately, solutions are already available. They are a bit dull, but arguably that is what science needs: to rediscover its dullness. There will still be plenty of discoveries, and most of them will turn out to be (provisionally) true.

As a media outlet, *New Scientist* isn't exempt from the challenge. We should redouble our efforts to apply caution to our reporting and to sniff out hype. If science doesn't reform itself, the only people who will ultimately benefit are anti-science voices such as climate change deniers and flat-Earthers. Science owes it to itself and the world to not let that happen. ▮

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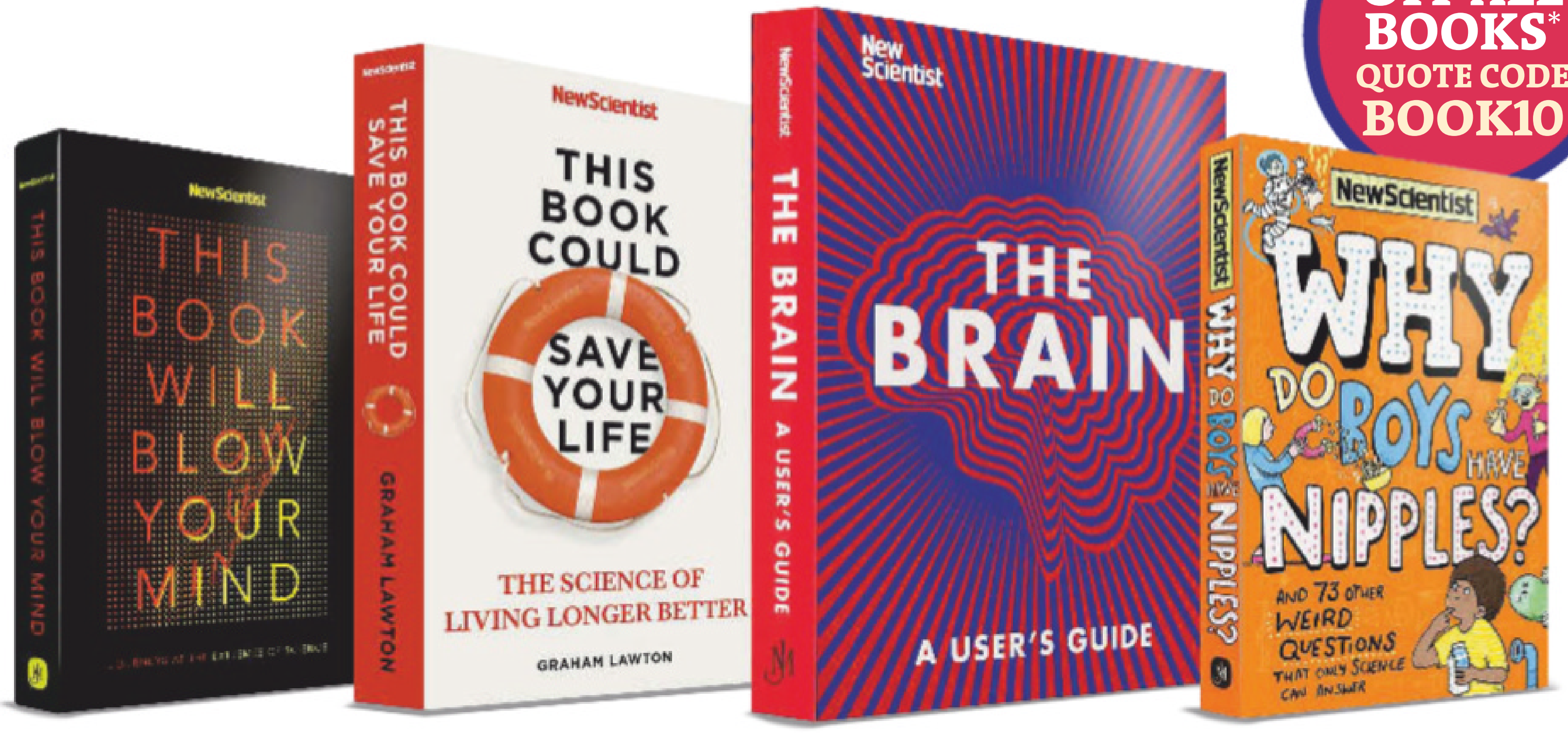
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Nurses check people at a coronavirus testing centre in Auckland

New Zealand's new battle

The return of covid-19 to the country after more than 100 days free of infections shows that nobody can relax, reports **Alice Klein**

A FRESH outbreak of covid-19 in New Zealand following its elimination there is a sobering reminder of how the virus can evade the toughest defences. The country has responded swiftly, but it remains to be seen if it can beat the virus again.

New Zealand declared zero remaining covid-19 cases on 8 June after enacting one of the strictest lockdowns in the world. Restrictions were eased, but it has since sought to keep the virus out with tight border controls that include a ban on international visitors, quarantining its citizens who return from abroad and requiring protective equipment for all airport and seaport workers.

These measures allowed New Zealand to go 102 days without recording any new locally acquired covid-19 cases. However, on 11 August, the country was rocked by news that four members of a family in Auckland had tested positive for the virus, without any identifiable source of infection.

"It's something we had been preparing for, but it's still a shock when it happens, particularly after having a three-month dream run," says Michael Baker at the University of Otago, who sits on the New Zealand government's covid-19 advisory panel.

In line with its "go hard, go early" strategy for the virus, the government put Auckland in lockdown the next day, banning residents from leaving home for non-essential reasons.

Authorities in Auckland also began testing anyone with even remote connections to the new cases, as well as all port workers, staff at quarantine facilities and anyone with cold and flu symptoms, in an effort to find out where the virus had come from and how far it had spread.

By 18 August, this testing blitz had identified another 65 cases connected to the original family cluster, as well as one in a man employed at a quarantine facility.

Baker is confident the virus has been caught early and has had little chance to spread, since almost all cases are connected to the same cluster and the number of new daily cases isn't rising. "All the signs are very positive at the moment that we'll be able to contain it again," he says.

Genetic sequencing suggests the new outbreak has been caused by a coronavirus strain that recently entered New Zealand. It most closely resembles a strain that is currently circulating in England, but how it sneaked into New Zealand is still a mystery.

One suggestion is that it entered the country in a frozen food shipment, since one member of the Auckland family that first tested positive works at a chilled food warehouse. "But so far there's been no evidence for this infection route," says Amanda Kvalsvig at the University of Otago.

> **"It's something we had been preparing for, but it's still a shock after a three-month dream run"**

Alternatively, a returning citizen with the virus may have incubated it for longer than normal – so it wasn't picked up by testing during quarantine – and then entered the community, says Siouxsie Wiles at the University of Auckland.

Although the new outbreak is a psychological blow, most Auckland residents seem to have willingly returned to lockdown, says Wiles. This may be because they have seen events play out in countries that have been slow to react to new outbreaks, she says.

Australia, for example, which also came tantalisingly close to eliminating covid-19, took more than a month to reintroduce stay-at-home orders in the state of Victoria after the virus escaped from a hotel used for quarantine. As a result, Victoria now has more than 7000 active cases and a rapidly mounting death toll.

Wiles believes that Auckland should remain in lockdown until the number of new daily cases returns to zero, which could be a week or two away. "The next few days will be crucial, so we're just watching and waiting," she says. ■

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Lockdown strategy

Sweden's virus response analysed

The Scandinavian country avoided compulsory lockdowns as the coronavirus spread. It isn't clear if this was a wise choice, says **Michael Le Page**

AARON GEDDES PHOTOGRAPHY/GETTY IMAGES

Sweden's capital Stockholm had a voluntary lockdown

SWEDEN was one of the few European countries not to impose a compulsory coronavirus lockdown. Its strategy for tackling the outbreak has been hailed as a success by some and condemned as a failure by others. Which is it?

While it is sometimes implied that Sweden didn't have a lockdown, it did. It was just largely voluntary, with only a few legal measures such as a ban on gatherings of more than 50 people. "Voluntary restrictions work as well as legal ones," says the architect of Sweden's strategy, chief epidemiologist Anders Tegnell.

This appears to be true, in Sweden at least. The measures did work nearly as well in getting people to change their behaviour. Adam Sheridan at the University of Copenhagen in Denmark, for instance, has used data from a bank to compare spending patterns up to April in Sweden and Denmark. Denmark introduced a compulsory lockdown on 11 March, one of the first in Europe.

Sheridan found that spending, which is an indicator of behaviour as well as economic activity, fell by nearly as much in Sweden as in Denmark: 25 per cent compared with 29 per cent.

Similarly, data from the Citymapper phone app, which helps people plan their routes, suggests that travel in Stockholm fell to 40 per cent of the normal level. "That's a substantial reduction," says Martin McKee at the London School of Hygiene & Tropical Medicine, whose team did the analysis. But there were even bigger falls in other major European cities with compulsory lockdowns, to around 20 per cent.

So there was a substantial voluntary lockdown in Sweden, yet it wasn't as effective in reducing the spread of the coronavirus as the compulsory lockdowns in neighbouring Denmark and Norway. Cases and deaths rose faster in Sweden, and have been slower to decline.

Sweden has about 8340 confirmed cases per million people as of 17 August, compared with 1815 in Norway and 2695 in Denmark. (For the UK, it is 4690 and 16,320 for the US.) Sweden has had 57 deaths per 100,000 people, compared with five in Norway and 11 in Denmark. (For the UK, it is 61, and for the US it is 51.)

> **"The economic impact was only slightly reduced by not imposing a more effective compulsory lockdown"**

Sheridan's analysis suggests young people – whose spending makes little contribution to the overall economy – were least likely to change their behaviour and might have undermined the voluntary lockdown. Among people aged between 18 and 29, spending dropped far less in Sweden than in Denmark.

Tegnell, meanwhile, says the high death rate in Sweden was related to the failure to prevent infections in care homes. Matters have now been improved, he says. Half of Sweden's deaths were in care homes up to mid-May.

What about the economy? "This has never been done to save the economy. It's been done to save public health," says Tegnell. That means public health in a broad sense, he adds, not just the coronavirus.

That said, Sheridan's spending comparison suggests that the economic impact was only slightly reduced by not imposing a more effective compulsory lockdown.

What's more, recent data released by another bank indicates that spending in Denmark has recovered faster than in Sweden, says Sheridan.

Others have claimed that Sweden suffered less of an economic decline on the basis of initial estimates of GDP for the second quarter of 2020. Sweden's fell by 8.6 per cent, less than the estimated average of 11.9 per cent for the European Union (EU) as a whole.

However, those making such claims fail to point out that several countries that did impose compulsory lockdowns did as well or better. GDP fell by 8.4 per cent in the Czech Republic, for instance, and by just 5.1 per cent in Lithuania, the lowest in the EU.

What all the researchers agree on is that it isn't over yet. There might be second waves in Denmark and Norway that Sweden avoids because so many people there have already been infected, although it is too soon to compare figures.

Achieving herd immunity (see page 10) was one of Tegnell's aims, but antibody surveys suggest that only about 20 per cent of people in Stockholm have been infected, similar to levels in London and New York. That is far short of the roughly 70 per cent level estimated to be needed. ▮

Coronavirus Essential Guide
All you need to know about coronavirus and covid-19
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Malnutrition

India's lockdown hits school lunch scheme that feeds 115 million

Nilanjana Bhowmick

A STAGGERING 115 million children in India are at risk of malnutrition, as the world's largest school lunch programme has been disrupted by the coronavirus pandemic.

When India went under a strict lockdown on 24 March to reduce the spread of the virus, 12-year-old Kavi's life changed. His mother, a roadside tailor, was no longer able to work and his father doesn't have a job due to health problems. With schools closed, Kavi began selling fruit and vegetables from a sparsely stocked cart.

This is now their primary source of income, but it isn't enough for a family of four. "Some days, we just eat rice or chapati with salt," says Kavi.

Before lockdown, Kavi was guaranteed a nutritious meal of rice, lentils and vegetables under India's state-run school lunch programme. As many as 115 million children between the ages of 6 and 14 used the scheme, which helped towards reaching their daily dietary requirements. The programme aimed to address India's chronic malnutrition problem: of the 1 million deaths of children under 5 in India in 2017, around 700,000 were attributed to malnutrition.

In 2019, a report funded by UNICEF found that more than 80 per cent of adolescents in India experienced a hidden malnutrition – deficiency in one or more micronutrients, such as iron, folate, zinc, vitamin A, vitamin B12 and vitamin D.

Access to this vital scheme has been impaired by the pandemic. "States have been repeatedly urged to ensure children continued to receive their food entitlements to maintain their nutritional status," says Ritu Aggarwal, a director of the lunch scheme.

In some states, teachers have been delivering uncooked rice, potatoes or lentils to children's homes, while in others parents are given a cash equivalent.

But this hasn't been an effective solution, says Samuel Scott at the International Food Policy Research Institute in New Delhi.

Apart from the fact that the money that reaches the children is only around 150 rupees ($2) per month, it is also impossible to ensure that the cash or food is used solely for the child, he says.

"Take-home meals are falling short in tackling the health and nutrition challenges of children because they have to share the meals with their siblings and parents," says Anjula Gurtoo at the Bengaluru-based Indian Institute of Science.

Children in Bihar enjoying a free lunch before schools in India closed due to covid-19

PAULA BRONSTEIN/THE VERBATIM AGENCY/GETTY IMAGES

In the long run, this could lead to a "weakened immune system, fatigue and risk of communicable disease along with severe effects on physical, emotional and psychological development", she says.

On 29 July, the Indian government updated the country's education policy, stressing children's health and nutrition. Under the new strategy, schools will supplement the midday meals with breakfast to address "the nutrition and health (including mental health) of children" through healthy meals, once a phased reopening begins in September.

Reopening schools is critical, says Scott. "Until then, I can't see Indian children getting the nutrition they are entitled to through the midday meal scheme." ▮

Pets

Can pets contract the coronavirus and spread it to people?

THE first confirmed case of a pet infected with SARS-CoV-2 – the virus that causes covid-19 – was a dog in Hong Kong in February. Since then, there have been at least 26 more confirmed cases in pet cats and dogs globally. Should pet owners be worried?

"We don't know how many pets have been infected because testing of animals is not done extensively," says Suresh Kuchipudi at Pennsylvania State University.

A small study led by Qiang Zhang at Huazhong Agricultural University and Huajun Zhang at the Chinese Academy of Sciences found that 11 of 102 cats tested in Wuhan, China, had antibodies showing they had been infected with SARS-CoV-2.

An ongoing study by Sarah Hamer at Texas A&M University and her colleagues tested the pets of 50 US owners with covid-19 and found three infected cats and one dog. "These are animals that are at high risk – they're in contact with positive people – so the fact that we've only found four infected pets suggests it's not very common," says Hamer.

Most pets with confirmed infections have displayed only mild symptoms. Of the four identified by Hamer's team, two had no obvious symptoms, one was sneezing and the other seemed overly sleepy. Yet it is possible that the virus could cause more severe illness in older pets or those with health conditions.

To be safe, owners with covid-19 should stay as far from their pets as possible, says Angel Almendros at City University of Hong Kong.

As for whether pets can transmit SARS-CoV-2 to people, experiments led by Jürgen Richt at Kent State University in Ohio have shown that it can pass between cats, but potential cat-to-human transmission is harder to study. The team is looking for genetic signatures in the virus that may reveal if an infection in a person has come from a cat.

> "We should extend social distancing rules to animals until we know more about the risk"

Kuchipudi believes that the risk of catching covid-19 from pets is probably low, but thinks we should extend social distancing rules to animals until we know more. He recommends keeping cats indoors and staying away from other dog walkers when you are out. ▮

Alice Klein

Transmission

Can herd immunity ever happen?

Claims that some countries may have achieved the threshold oversimplify the issue

Jessica Hamzelou

THE idea of herd immunity has had a bumpy ride as the coronavirus pandemic has played out. It was initially touted in some countries as a viable strategy for dealing with the spread of covid-19, before being dismissed. Today, some headlines celebrate the fact that many places might have achieved herd immunity including Britain and pockets of London, New York and Mumbai. But others warn that millions will die before we get there.

The true picture is far messier, partly because scientists don't even agree on what herd immunity is, let alone how it might be achieved. So how will we know when populations are protected against the coronavirus?

While the definition of herd immunity depends on who you ask, let's assume that it refers to a situation in which enough of a population is immune to a pathogen that it no longer spreads throughout a community. Those who might be susceptible to it are indirectly protected thanks to the immune responses of others.

These immune responses might have developed after a person was infected with a pathogen or after being vaccinated against it.

Our experience of other viruses show how herd immunity can develop. Seasonal viruses like the common cold often sweep through a population until enough people have encountered them and built up a protective immune response for them to stop spreading. Widespread use of the MMR vaccine led to herd immunity for measles in some countries.

But herd immunity doesn't necessarily last. Viruses can evolve and change. And if vaccination rates drop, viruses can make a comeback.

When it comes to the coronavirus, there are even more challenges. For a start, we don't know what proportion of a population would need to be immune to generate herd immunity. This figure is typically estimated using the basic reproduction number – or R number – of a virus, which represents how many other people a person who has the virus will go on to infect.

10-20%

Infection rate needed to reach herd immunity, according to one study

Most estimates say that between 60 and 70 per cent of a population would need to be immune to the coronavirus to stop its spread in a community. That is based on an R number of somewhere between 2.5 and 3.

But even if these levels were reached, it doesn't mean that the virus won't spread at all. It could still be passed from an infected person to someone who is vulnerable, given the right setting. "It's a population-level statistic," says Julian Tang at the University of Leicester, UK. It is difficult to know when herd immunity has been reached, but a decline in cases would be a good indicator.

The problem is that humans don't tend to behave as a herd. The calculation for the herd immunity threshold assumes that people are equally spaced and mixing equally with each other. In other words, "no walls, barriers, cars or glass windows in the way", says Tang. In reality, of course, people live in varied environments, and travel and interact with others to varying degrees.

Estimates of the R number vary, too, and change over time. Our behaviour can also influence the figure. Lockdowns, social distancing and other infection control measures will have lowered the R number in many regions, for example.

Violinist Ara Malikian performs in Madrid during the pandemic

JUANJO MARTIN/EPA-EFE/SHUTTERSTOCK

This line of thought led Gabriela Gomes at the University of Strathclyde, UK, and her colleagues to recalculate the herd immunity threshold. The team developed a mathematical model based on the simple herd immunity calculation, but tried to factor in variation between individuals.

Already immune

In theory, this variation takes into account the differences across a population in susceptibility to the virus, and the chances of people coming into contact with it. The more variation there is, the lower the threshold for herd immunity, says Gomes. By her team's calculations, only around 10 to 20 per cent of a population needs to be immune to the virus to achieve herd immunity (medRxiv, doi.org/10/d6sh).

By that estimate, some places have already achieved herd immunity. More than 10 per cent of the population of Madrid is thought to have developed some immunity to the virus, for example. "In Europe, I think most countries are close to having that status," says Gomes. This would suggest that the epidemic is currently at its peak in places like Madrid, she says.

Samir Bhatt at Imperial College London disagrees. "I personally don't believe we're anywhere near herd immunity," he says. He points to regions with exceptionally large outbreaks, such as Bergamo in Italy, where 57 per cent of people tested between April and June had antibodies to the virus. "If 10 per cent were sufficient, why did they get up that high?" Bhatt asks.

One issue is that estimates for the threshold vary so wildly, anywhere from 10 to 70 per cent.

"It's impossible to actually calculate herd immunity," says Bhatt. "There's no simple answer," says Luis Barreiro at the University of Chicago.

Given the uncertainty, most scientists believe it would be unethical to wait for enough people to become infected with the virus to establish herd immunity. Estimates for hard-hit countries like France, Spain and Brazil suggest that only around 5 to 10 per cent of the population have encountered the virus, leaving the majority vulnerable. "The number of people that would die from the virus would be astronomic," says Barreiro.

In theory, a vaccine could provide a safer route to herd immunity. But many questions remain as to how effective a vaccine will be. We still don't know, for example, how long a person's immune response to the virus lasts – whether they become infected with the virus or receive a vaccine. If a vaccine only reduces a person's risk of infection by 50 per cent, for example, "the threshold becomes much higher, and realistically it becomes impossible to ever reach herd immunity", says Barreiro.

Even if a vaccine does provide good protection, it might not work for everyone. Some may protect young people, but not older individuals who don't mount as strong an immune response.

The public's perception of a vaccine is also important. A recent Gallup poll suggests that 35 per cent of people in the US would refuse a vaccine against the virus, while a UK survey found 16 per cent of people said they would be unlikely, or refuse, to take one."If 20 to 30 per cent of the population refuses a vaccine, we will probably never be able to reach herd immunity," says Barreiro. ▮

Briefing

Russia's new vaccine

Vladimir Putin has announced that Russia has approved a coronavirus vaccine, but is it safe, asks **Michael Marshall**

MINZDRAV/HANDOUT/EPA-EFE/SHUTTERSTOCK

Containers of the newly registered Russian vaccine

RUSSIAN president Vladimir Putin announced on 11 August that the country has approved a coronavirus vaccine. Putin said that the vaccine is safe and effective. Russia apparently plans to start mass vaccinations in October.

The news has caused global concern, with immunologists saying that Russia seems to be cutting corners.

What do we know about the vaccine?

The vaccine has been dubbed "Sputnik V", in reference to the first artificial satellite, Sputnik 1, launched by the USSR in 1957. It seems a sign that the Russian government plans to trumpet it as a matter of national pride. The vaccine has been developed by the Gamaleya Research Institute of Epidemiology and Microbiology in Moscow, part of Russia's Ministry of Health.

The vaccine would be administered in two shots, 21 days apart. Both shots contain modified adenoviruses, which would ordinarily cause a common cold. Both have been given the gene for the spike protein from the new coronavirus. This protein allows the virus to enter human cells. In theory, this should prime the immune system for an encounter with the actual virus.

> "We can't have any confidence in the vaccine when we don't have transparency"

What tests has it been through?

After going through phase I and II trials for safety and efficacy, new vaccines must normally go through one or more large phase III trials, to find out whether the vaccine actually protects against infection. This isn't just a formality: a vaccine might trigger an immune response in phase II, but this may not be enough to confer real immunity in phase III.

The Russian researchers have preregistered phase I and phase II trials, and according to one website for the vaccine, these trials were completed in early August. It claims that there were no adverse effects and that the vaccine triggered the desired immune response. But no detailed results have been released. It also says that a phase III trial was due to start on 11 August in several countries.

In other words, the vaccine hasn't been through the full gamut of tests. Without the data from phase I and II, we don't know how safe it is. And without phase III, we don't know if it works. "We can't have any confidence when there's no transparency," says Scott Ratzan at the City University of New York.

Is this a good idea?

Public-health experts have identified several ways in which the Russian move could backfire.

Most obviously, the vaccine may cause serious side effects. Adenovirus-based vaccines have been widely used, so the risk is arguably low, but without trial data, we cannot be sure.

The vaccine also may not provide protection against the coronavirus. If people take it and believe themselves to be immune when they aren't, the virus could spread more widely and cause many more deaths.

And many countries already have problems controlling existing diseases through vaccination because people are reluctant to vaccinate themselves or their children. This is due to the anti-vaccine movement's false claims that existing vaccines are dangerous. Releasing an untested vaccine could exacerbate the problem.

"There's some that will be refusers, some deniers that vaccines don't work, and then there's the hesitant group that aren't sure, in the middle, and that's what the concern is," says Ratzan. ▮

Global tourism

Travel in the age of covid-19

As coronavirus cases fluctuate around the world, what are the best strategies for allowing foreign travel? **Clare Wilson** investigates

IN THE past few weeks, many holiday plans have been dashed after some parts of Europe, including the UK, reintroduced travel restrictions. Even UK transport secretary Grant Shapps had to cut short his holiday to Spain and follow it with two weeks' home quarantine.

It is a stark change from June, when the UK government was encouraging people to holiday abroad to boost the travel industry. Since then, many countries have seen an increase in coronavirus cases, making going abroad more of a gamble. So what are the different options for managing the current risks from international travel, and which countries have got it right?

When the pandemic began, the World Health Organization initially discouraged travel bans, saying that they would worsen economic damage without slowing the virus's spread. But some countries that adopted strict border controls, like New Zealand and Taiwan, have been among the most successful at controlling the coronavirus.

"Even one week of quarantine may make short trips abroad unappealing for many"

These countries haven't stopped foreign trade, only leisure travel, with business travellers now meeting online. "To the extent we were worried we were going to crash the world's economy if we restricted travel, it doesn't appear to have happened," says David Hunter at the University of Oxford.

However, foreign tourism is a large chunk of the economy in many places, so some foreign travel has restarted through "corridors", where countries with a similar prevalence of coronavirus allow free movement between them.

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DANIEL COLE/AP/SHUTTERSTOCK

People queuing at Nice airport in France for a flight to the UK

Corridors are in place between the UK and countries including Italy and Germany. But this arrangement leaves little certainty, because coronavirus rates change. For instance, the UK last week took France, Malta and the Netherlands off its list of travel corridor countries. "In the time between when people book a trip and when they come back, the circumstances may change," says Hunter.

Some in the travel industry have called for quarantine to be avoided by instead having health checks on arrival. Indeed many airports, including some in the UK, check people's temperature before or after flights to try to screen out those carrying the virus.

However, while fever is a common symptom of covid-19, about four in 10 of those who catch the virus have no symptoms at all.

Many places, such as Germany and France, are giving arrivals from high-risk countries a swab test for the virus – the same one that people get if they have symptoms. Some tests are fast enough that people can wait at the airport until they get the all-clear. Thailand has begun offering some travellers a 90-minute test so they can avoid quarantine and similarly rapid tests will soon be rolled out in the UK.

False negatives

But many coronavirus tests have a high rate of false negatives – wrongly giving someone the all-clear – especially early on in the disease. A review of seven previous studies suggests that on the first day after infection, everyone tests negative, and even on day four, the false negative rate is 67 per cent.

The safest approach is quarantine. In the UK, people have to stay at home for 14 days after arriving from abroad, unless they have come from an exempt country. Other places such as Australia, New Zealand and South Korea make people who are self-isolating stay in designated hotels to ensure they stick to the rules.

A breakdown in this strategy may explain why cases in the state of Victoria in Australia shot up. Most other Australian states have been using police to supervise quarantine facilities, but Victoria hired private contractors, some of whom caught the virus and passed it on, allegedly because of lapses in procedures.

There may be a way to make quarantine less onerous. Last month, Billy Quilty at the London School of Hygiene & Tropical Medicine and his team released modelling work showing that the length of time for which people self-isolate could be cut to eight days, if they have a virus test on day seven and get the result the next day.

This would cut the number of infectious new arrivals by 94 per cent, compared with 99 per cent for a two-week quarantine, the team says. Such a strategy might be acceptable for many countries, but would be unlikely to satisfy those like New Zealand that are trying to eliminate the virus from their shores.

Even one week of quarantine may make short trips abroad seem unappealing for many. Hunter has argued that people should give up on vacations abroad this year and holiday in their home country instead. It might have been less disruptive if countries had settled for such a compromise in the first place. ▮

Cybersecurity

Ambulances vulnerable to attack

Some devices in UK ambulances are still relying on an outdated operating system

Phee Waterfield

HUNDREDS of ambulances in the UK are still using devices that run on defunct Windows operating systems, making them more vulnerable to cyberattacks. The WannaCry ransomware that knocked out computers at dozens of hospitals in 2017 took advantage of a similar vulnerability.

According to data obtained through Freedom of Information (FOI) requests, North East Ambulance Service and Yorkshire Ambulance Service use devices in their ambulances daily that run on Windows XP.

About 500 vehicles run by the Yorkshire Ambulance Service have a mobile device terminal that controls a vehicle's GPS navigation and deals with status messages, such as where a patient lives and the type of emergency. Some 350 run on Windows XP, which hasn't been supported by Microsoft since April 2014. Yorkshire Ambulance Service says it will update these by 15 October.

North East Ambulance Service runs XP on devices in 550 vehicles. London Ambulance Service also said it has five XP devices, but they aren't connected to the internet.

New Scientist put in FOI requests to all the ambulance trusts in England last year asking whether devices within each trust ran on Windows XP, Windows 98 or Windows 95. Only those mentioned in this article were using obsolete versions of Windows and all three declined to provide additional comment.

"In each dual crewed ambulance and rapid response vehicle there is a mobile data terminal, which is controlled by a third party company, Terrafix," said Yorkshire Ambulance Service in its FOI response. Terrafix didn't respond to *New Scientist*'s request for comment.

"Terrafix provides systems to many ambulances, so is a high-level potential target for hackers, cybercriminals and cyberwarfare attacks," says Ray Walsh at advocacy group ProPrivacy. "The company is responsible for systems that provide the information that first responders and paramedics receive while on call," he says. "If it were to be hacked, cybercriminals could potentially get a hold of any patient data that is provided by the mobile data terminal in the ambulance or, worse, interfere with the vital information that enables the ambulance to get to the patient quickly."

Ambulances have data terminals for getting patient information

JAMES WALSH/ALAMY

Windows XP no longer gets security updates. Potential consequences were seen in 2017, when the WannaCry ransomwear attacks took down hundreds of thousands of computers worldwide. More than 60 UK National Health Service trusts were affected, which prevented doctors from accessing patient records and forced the cancellation of many procedures.

WannaCry exploited computers that hadn't been updated with the latest Windows security patches or that ran versions of the operating system that Microsoft no longer supported. ▮

Physics

Magnetic levitation separates living cells from the dead

A FORM of magnetic levitation can separate living and dead cells without altering or damaging them in any way. The process could be used for everything from drug discovery to tissue engineering.

Cells normally sink to the bottom of the fluid they are in. Gozde Durmus at Stanford University in California and her colleagues have developed a way of "levitating" them by using magnetism.

"Everything on Earth is magnetic," says Durmus. Her team puts cells in a fluid containing ions of the rare earth metal gadolinium, which is weakly magnetic, or paramagnetic. This form of gadolinium is non-toxic, and is injected into people to improve contrast in MRI images.

The fluid is then put inside a glass tube with cheap, simple magnets above and below it. The end result is an upward magnetic force on the cells that opposes gravity, so they float in the tube at a level that depends on their density.

"It's pretty simple to do," says Durmus, who first described the technique in 2015 and has since been working on applications. "Anybody can make these devices."

In her latest study, Durmus has shown that this method can be used to separate living and dead cells, because the density of cells increases after death. There are various ways of doing this already, such as spinning cells in a centrifuge, but these existing processes damage fragile cells.

"We could use the technique to see what levels of a drug are required to kill cancerous cells"

Levitation is much gentler, says Durmus, and allows people to observe the process as it happens, because dying cells start sinking straight away. "We can pretty much watch cell death in real time," she says (bioRxiv, doi.org/d6nr).

The technique could have all sorts of applications in medicine. For instance, we could add drugs and watch to see what levels are toxic to healthy cells, or required to kill cancerous cells. It also works with bacteria, says Durmus, so could help antibiotic development. ▮

Michael Le Page

Biodiversity

Rare plant threatened by quarry

Plan to open the first lithium and boron quarry in the US could be stopped by a plant

Ian Morse

AN AUSTRALIAN mining firm wants to turn a Nevada valley into a quarry for lithium and boron – key elements for green technologies – but a rare plant may stand in its way. Researchers say that biodiversity and clean energy shouldn't be in opposition.

The company, Ioneer, says the quarry in Rhyolite Ridge valley would be the first US quarry of its kind, able to supply lithium for 400,000 electric car batteries a year and boron for wind turbines. But soil containing these elements is also the perfect environment for Tiehm's buckwheat (*Eriogonum tiehmii*). When it blooms, the plant could be the dandelion's fuzzy cousin.

There are only about 40,000 specimens of the buckwheat, and its namesake, Arnold Tiehm at the University of Nevada, Reno, says its closest relative is more than 80 kilometres away.

Most of the plant's natural home lies in the area mapped to be dug up for the quarry. "That puts the buckwheat on a one-way path to extinction," says Patrick Donnelly at the Center for Biological Diversity (CBD) in Nevada. Ioneer will remove 65 per cent of the buckwheat's population if the first planned quarry goes ahead, the firm confirmed to *New Scientist*.

Although rare, the buckwheat isn't yet considered endangered, but that may change. Following a petition by the CBD, the US Fish and Wildlife Service announced in July that the plant is both valuable enough and under sufficient threat to warrant a year-long review to decide whether to list it under the US Endangered Species Act. The listing would spell the end for the quarry as planned.

Most lithium is mined in South American or Australian deserts. Ioneer is one of a few companies looking to begin US production.

"The choice is to rely solely on other countries around the world, including those with repressive regimes, poverty, water shortages and poor environmental compliance, or to develop domestic supply under the highest possible standards," says Bernard Rowe of Ioneer USA Corporation, Ioneer's US subsidiary.

Believing that the quarry and buckwheat can coexist, Ioneer has funded researchers at the University of Nevada, Reno, to monitor and study relocation options for the buckwheat.

There are only about 40,000 Tiehm's buckwheat plants

PATRICK DONNELLY/CENTER FOR BIOLOGICAL DIVERSITY

Discovered in 1983, much is unknown about the plant. Its population has hardly changed since then, says Tiehm. Research on its interaction with soil and pollinators began only this year, according to Ioneer's environmental consultant.

"The best way to conserve it is to protect the place where it grows," says Naomi Fraga at the California Botanic Garden, who wrote an additional petition to the state of Nevada this year, signed by 91 scientists. They write that they don't oppose lithium mining, and that it doesn't make sense to weigh the benefits of clean energy against protecting biodiversity, particularly as the buckwheat was already in a precarious position.

"It's like with the covid-19 pandemic," says Fraga. "People were saying that if a patient is already vulnerable or already sick, what are the ethics of deciding who gets care? We shouldn't be in the position to pick and choose who gets to survive." ▮

Astronomy

Galaxy's fastest star moves at 8 per cent the speed of light

ASTRONOMERS have spotted the fastest star ever. S4714, the newly discovered star, travels at 8 per cent of the speed of light. It orbits close to the supermassive black hole at the centre of the Milky Way and could be the best place in the galaxy to test Albert Einstein's theory of general relativity.

It is hard to spot stars orbiting Sagittarius A*, the Milky Way's central black hole, because the galaxy gets increasingly crowded the closer you get to its middle. But Florian Peissker at the University of Cologne in Germany and his colleagues have used the Very Large Telescope (VLT) in Chile to identify five new stars there.

They include S4714, which is more extreme than the others: its elliptical orbit takes it to a distance from the black hole that is just 12.6 times the size of the span between Earth and the sun.

It moves at a speed of nearly 24,000 kilometres per second – 8 per cent of the speed of light – which makes it the fastest-moving star we have ever seen (*The Astrophysical Journal*, doi.org/d6nv).

The view from such a star would be extreme. "The night sky would be awash with bright nearby stars," says Jessica Lu at the University of California, Berkeley.

"S4714 moves at 24,000 kilometres per second, making it the fastest-moving star ever seen"

You would be able to see not only the colossal black hole and the bright disk of matter falling into it, but also the strange effects of light stretching and warping around it, says Peissker.

These occur because of general relativity, a theory that describes the inner workings of gravity. The area near Sagittarius A* is the best place in the Milky Way to test that theory because the black hole's gravity is so powerful. ▮

Leah Crane

Ecology

Squirrel said to be carnivorous actually eats very hard seeds

Michael Le Page

THE Bornean tufted ground squirrel became known as the "vampire squirrel" because of tales of it slashing the jugular veins of small deer. But the first study of the animal's feeding habits has found it is a highly specialised seed eater.

Andrew Marshall at the University of Michigan is part of a team that has spent decades studying species in the forests of Gunung Palung National Park on the island of Borneo. He and his colleagues have now put together all the data on the tufted ground squirrels (*Rheithrosciurus macrotis*).

The squirrels have saw-like incisors, unlike any other mammals, and the most voluminous tail relative to body size of any mammal, making them seem much larger than they are.

"It's quite menacing, if a squirrel can ever be said to be menacing," says Marshall.

The squirrels came to the internet's attention in 2014, after a news story called them vampire squirrels. This moniker was based on stories told by the local Dayak people, who say the squirrels jump on the backs of deer, kill them by slashing their jugular veins and then disembowel and eat them.

But Marshall's team hasn't seen this happen. On 60 of the 79 occasions that his team observed the squirrels feeding, they were eating the extremely hard seeds of a big canopy tree called *Canarium decumanum*. On the other 19, they were eating similar seeds produced by a few other trees (bioRxiv, doi.org/d6nk).

While he thinks it is unlikely that the tufted squirrels attack deer, Marshall isn't ruling out the possibility that it happens occasionally, given that other Dayak stories have proved true in the past. "People who spend a lot of time in the forest see really unusual things," he says. ▮

Mental health

The hidden downsides of mindfulness

Clare Wilson

MARKO GEBER/GETTY IMAGES

Some people experience negative effects from meditation

MINDFULNESS and other types of meditation are usually seen as simple stress-relievers – but they can sometimes leave people worse off.

About one in 12 people who try meditation experience an unwanted negative effect, usually a worsening in depression or anxiety, or even the onset of these conditions for the first time, according to the first systematic review of the evidence.

"For most people, it works fine, but it has undoubtedly been overhyped and it's not universally benevolent," says Miguel Farias at Coventry University in the UK, one of the researchers behind the work.

There are many types of meditation, but one of the most popular is mindfulness, in which people pay attention to the present moment, focusing on either their own thoughts and feelings or external sensations. It is recommended by several National Health Service bodies in the UK as a way of reducing depression relapses in people who have experienced the condition several times.

"People have experienced anything from an increase in anxiety up to panic attacks"

Enthusiasm for meditation may partly stem from a growing awareness of the side effects of antidepressant medicines and the difficulties some people report in stopping taking them.

There have been some reports of people experiencing worse mental health after starting meditation, but it is unclear how often this happens.

Farias's team combed through medical journals and found 55 relevant studies. Once the researchers had excluded those that had deliberately set out to find negative effects, they worked out the prevalence of people who experienced harms within each study and then calculated the average, adjusted for the study size, a common method in this kind of analysis.

They found that about 8 per cent of people who try meditation experience an unwanted effect. "People have experienced anything from an increase in anxiety up to panic attacks," says Farias. They also found instances of psychosis or thoughts of suicide. The work will appear in *Acta Psychiatrica Scandinavica*.

The figure of 8 per cent may be an underestimate, as many studies of meditation record only serious negative effects or don't record them at all, says Farias.

Katie Sparks, a chartered psychologist and a member of the British Psychological Society, says the figure could have been pushed up by people trying out meditation because of undiagnosed anxiety or depression. "Meditation has been found to help people to relax and refocus and help them both mentally and physically," she says.

But sometimes when people are trying to still their thoughts, the mind can "rebel", she says. "It's like a backlash to the attempt to control the mind, and this results in an episode of anxiety or depression," she says.

This doesn't mean people should stop trying meditation, she says, but instead should opt for guided sessions, led by a teacher or an app with a recorded narration, which she believes is safer. "The current study could stop people participating in something which can be of benefit in the right context," she says. ▮

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Astronomy

A dish disaster

The iconic Arecibo Observatory has taken a massive blow

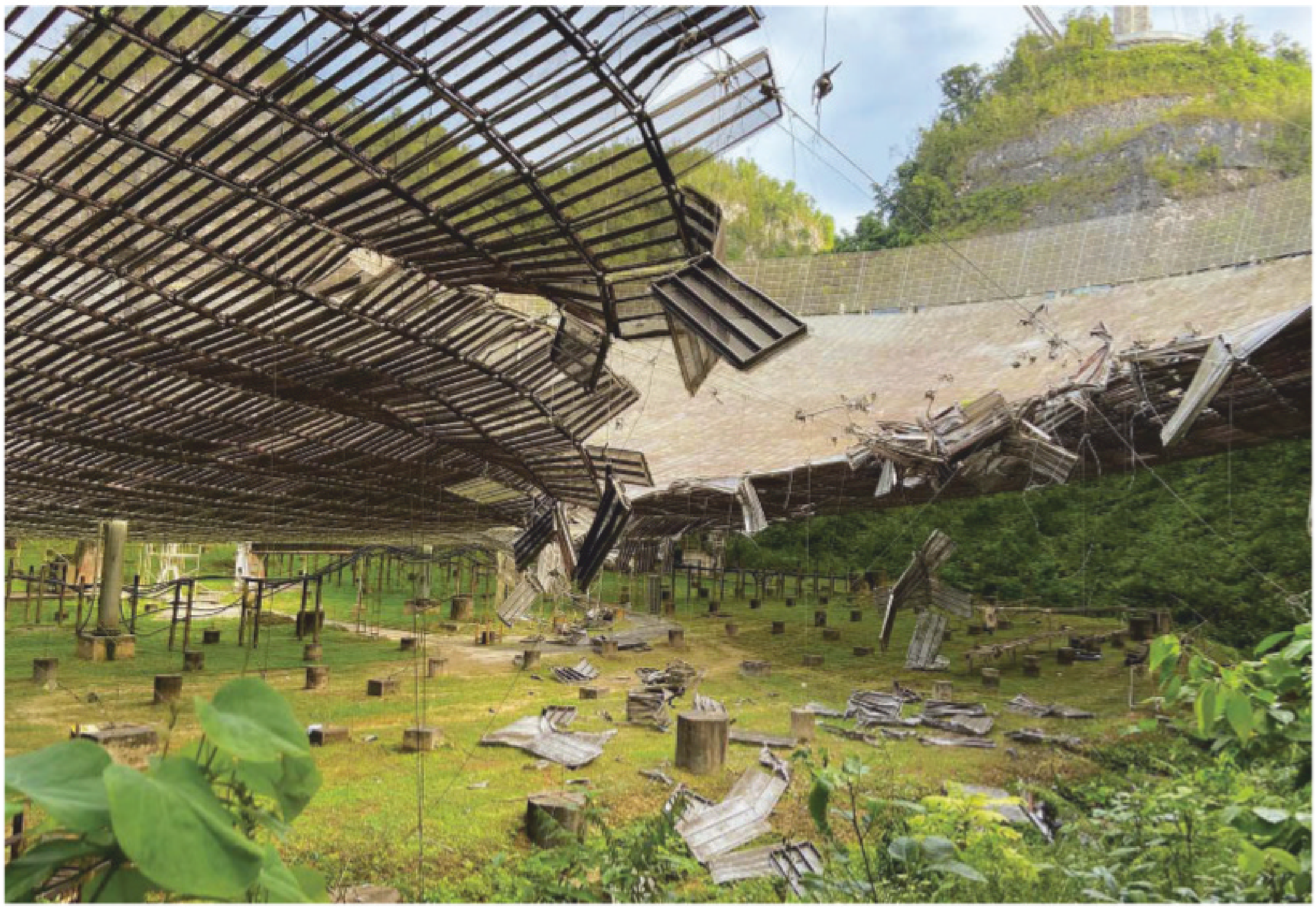
Leah Crane

ONE of the world's biggest radio telescopes has been damaged during a tropical storm. A cable at Arecibo Observatory in Puerto Rico snapped on 10 August, slashing a 30-metre-long hole in the telescope's 300-metre-wide dish.

The damage occurred during Tropical Storm Isaias, but according to the University of Central Florida, which helps run the observatory, it isn't yet clear whether the cable broke because of the storm.

"We have a team of experts assessing the situation," said Francisco Cordova, the director of the observatory, in a statement. "Our focus is assuring the safety of our staff, protecting the facilities and equipment and restoring the facility to full operations."

Arecibo has gone through tough times recently. Repairs from Hurricane Maria, which caused widespread damage in Puerto Rico in 2017, are still ongoing.



ARECIBO OBSERVATORY, UNIVERSITY OF CENTRAL FLORIDA

Animals

Treats beat shocks for dog training

IF YOU want to improve a dog's behaviour, a tasty treat is more likely to succeed than an electric shock, researchers have found.

"We advocate the use of reward-based training in modifying dog behaviour, as our work indicates it is more effective than training which involves aversive stimuli, and it carries fewer risks to dog welfare," says Jonathan Cooper at the University of Lincoln, UK.

Cooper and his colleagues compared the two training methods using 63 dogs split into three groups. All the animals required training for failing to come when called and for repeatedly chasing livestock.

The team asked professional handlers nominated by the Electronic Collar Manufacturers Association (ECMA), a trade group based in Brussels, Belgium, to train one group. They used e-collars that can deliver an electric shock along with additional methods, including pulling the dog's leash or offering food and praise. They also trained a second group using the same methods, but without the use of e-collars, as a control.

In the third group, professional members of the UK-based Association of Pet Dog Trainers used a training method that incorporates praise, play and food as rewards. All of the dogs were trained in the presence of penned livestock and wore 10-metre leashes and e-collars during the study, but the collars were turned off in the latter two groups.

Cooper and his colleagues found that those in the reward group responded to commands faster and with fewer reminders, he says. For example, the reward group came to the trainer on average 1.13 seconds after the "come" command, compared with 1.35 seconds for the e-collar group and 1.24 seconds for the control group (*Frontiers in Veterinary Science*, doi.org/d6kt).

"Dogs trained with rewards responded to the 'come' command after an average of 1.13 seconds"

"The e-collar trainers were good, as they consistently improved recall in dogs that were referred for poor recall, but the reward-based trainers were better," says Cooper.

ECMA spokesperson Jamie Penrith, who wasn't involved in the study, says the results don't mean e-collars aren't needed. "A food reward method is dependent on the owner being there to give the reward, but in 85 per cent of dog attacks on livestock, nobody is present," he says. "The e-collar conditions the dog to associate a livestock attack with something aversive, independent of the owner's presence."

Christa Lesté-Lasserre

Technology

Virtual assistant may put an end to annoying robocalls

Chris Stokel-Walker

NUISANCE phone calls could disappear with the help of a virtual assistant that screens spammers before the phone even rings.

Robocalls, in which an automated recording pretends to be a human, are a common problem – there are an estimated 4.9 million every hour in the US alone. Simple block lists can screen some of these out, but they are only around 60 per cent effective, says Sharbani Pandit at the Georgia Institute of Technology.

In an attempt to do better, Pandit and her colleagues have created a virtual assistant that acts as a buffer between the caller and the recipient. If a number isn't in a phone's contact list, the call-maker is diverted to the assistant and asked to state the recipient's name. "A person who knows my name is calling with a good intention – or they're not typical robocallers," says Pandit.

If the caller responds, the virtual assistant interrupts them, saying: "Sorry, I didn't get that. Can you please say who you are trying to reach again?" While a robocaller probably won't notice the question, a human is likely to stop talking. If they do, the virtual assistant passes on the call via an app, along with a transcribed name.

When tested on around 8000 recorded robocalls, the system blocked every single one. A further test with 21 human participants, in which the callers engaged with the virtual assistant but occasionally used the wrong name, was 97.8 per cent effective (arxiv.org/abs/2008.03554).

"It's like a spam filter that checks that the sender has at least minimal knowledge about the addressee and is flexible enough to produce that knowledge on request," says David Schlangen at the University of Potsdam, Germany. He says the system could be circumvented but that call spammers are unlikely to bother. ▮

Biology

Radio waves boost the growth of plants

Jo Marchant

A DOSE of radio waves seems to encourage plant seedlings to grow faster. If confirmed, the find could have applications from farming to medicine.

Margaret Ahmad at Sorbonne University in Paris, France, and her colleagues exposed thale cress seedlings (*Arabidopsis thaliana*) to weak pulses of radio frequency (RF) radiation at 7 megahertz, a frequency used by amateur radio operators.

The team found that this altered the activity of a type of light sensor in the plants called a cryptochrome. The expression of several genes regulated by the sensor also changed, and the seedlings grew slightly faster.

> "This is the first time anyone has found a biological receptor sensitive to radio waves"

This is the first time anyone has found a biological receptor sensitive to radio waves, says Ahmad. "What we showed is that we can manipulate the chemistry of the cryptochrome receptor in living plants by a remote radio frequency signal."

Cryptochromes are proteins found across biology in insects, birds and mammals, including humans. They have many functions, from regulating plant growth rates and biological clocks to helping birds navigate. They are thought to sense weak magnetic fields in many species, through a quantum mechanism in which the field alters the rate at which the protein is activated by light.

Ahmad, who discovered cryptochromes in the 1980s, wondered if these receptors might also be sensitive to radio waves. Extremely weak RF radiation is known to disrupt magnetosensing in birds, insects and rodents, but the mechanism is unknown.

The team predicted that if the quantum cryptochrome theory is correct, RF radiation should also interfere with the cryptochrome sensor, blocking the effect of Earth's magnetic field. This is indeed what they found, with the seedlings in RF radiation responding in the same way as young plants in a null magnetic field (*Scientific Reports*, doi.org/d6mz).

The result strengthens the idea that human-made electromagnetic noise can have biological effects. The signals used by Ahmad's team were about 10 times higher than the radiation emitted by radio transmissions or electrical appliances in a home, but she says the behaviour of birds and insects can be affected by far lower intensities.

Alfonso Balmori, a biologist in Valladolid, Spain, says this adds to evidence for biological effects that aren't currently considered in health and safety standards for telecommunications networks. There is still lots we don't know, he says, "so we should always apply the precautionary principle".

The growth of thale cress can be affected by radio frequency radiation

PIERRE BRYE/ALAMY

David Keays at the Research Institute of Molecular Pathology in Vienna, Austria, says the effect is interesting, but needs to be replicated. He says any effect on wildlife is likely to be small. Birds use several different methods to orientate themselves, he says, including visual cues, so can probably work around any electromagnetic noise.

"My suspicion is that climate change and light pollution have a much larger impact," he says. He also emphasises that the research in no way supports conspiracy theories relating to 5G cellular networks spreading the coronavirus.

Cryptochrome reactions produce potentially toxic chemicals called reactive oxygen species. These can be harmful at high levels, but at smaller doses, they activate cellular repair and stress response mechanisms.

Ahmad suspects that organisms would quickly adapt to low-level, continuous RF radiation in the environment. But she believes short, tailored pulses of radio waves could prove useful. Farmers might use radio masts to trigger stress responses in crops, making them more robust against drought or pests, she says. In medicine, she says, RF pulses might help to trigger repair mechanisms in specific tissues. "The potential for therapy is very real," she says.

Keays, however, says he doesn't think the effects could ever be large enough to be useful. ▮

DOUG PERRINE/NATUREPL.COM

Marine biology

Reef sharks hang out with the same friends for years

GREY reef sharks chill with the same buddies in the same spot for years, a four-year study at the remote Palmyra Atoll in the Pacific Ocean has revealed.

Yannis Papastamatiou at Florida International University in Miami and his colleagues tagged about 40 sharks with acoustic transmitters that each emit a unique high-frequency sound. A network of 65 receivers recorded which sharks came within 300 metres or so of any receiver.

The recordings reveal that the social groups of grey reef sharks are remarkably stable: the same individuals associate year after year and movements between groups are rare (*Proceedings of the Royal Society B*, doi.org/d6nn).

"They purposely associate with the same individuals," says Papastamatiou. That suggests that they can recognise other sharks individually.

Grey reef sharks (*Carcharhinus amblyrhynchos*) are most active at night. During the day, they return to a particular spot on the reef, forming groups of 20 or so. They do catch prey during the day, but feed more at night.

It isn't known whether the same individuals hunt together when they leave the home area at night. The grey reef sharks at Palmyra catch most of their prey in open waters, too far from the reef to be detected by the receiver network.

Grey reef sharks are unusual among sharks in being social animals. Other species, such as the great hammerhead, spend most of their time alone. **Michael Le Page**

Physics

All-consuming fire is three flames in one

WE ARE a step closer to solving the mystery of the blue whirl flame, a soot-free flame that consumes all the fuel it encounters.

The phenomenon was discovered in 2016 by researchers who were investigating efficient ways of using fire to clean up oil spills in the ocean. They were experimenting with fire whirls – whirlwinds naturally induced by fire – and accidentally generated a clean, whirling, blue flame.

Since then, people have been trying to determine the structure of this mysterious blue whirl flame, in the hope of harnessing it.

Joseph Chung and Xiao Zhang at the University of Maryland, College Park, and their colleagues created a computer simulation of the experimental conditions that generated the original flame. By gradually adjusting parameters, such as the ratio of fuel to air, and comparing it with video footage of the blue whirl, the researchers were able to simulate the flame and analyse its structure.

They discovered that the blue whirl is the result of three types of flame merging. These include an invisible outer flame, where there is more oxygen than fuel, and two visible inner flames, where the ratio of fuel to oxygen is higher (*Science Advances*, DOI: 10.1126/sciadv.aba0827).

Knowing its constituent flame types could enable the blue whirl to be recreated without needing to go through the dangerous, and hard-to-contain, fire whirlwind stage to produce it, says Chung.

It could also lead to combustion that is cleaner and produces fewer pollutants. "The blue whirl itself shows a possible way of burning that could greatly reduce this pollution and so we are very motivated to explore this potential for cleaner combustion," says Zhang. **Layal Liverpool**

Health

US kids are eating more fast food

OVER a third of children in the US eat fast food on any given day, according to survey results compiled by the US Centers for Disease Control and Prevention.

Cheryl Fryar at the CDC's National Center for Health Statistics and her colleagues have been tracking the fast-food intake of young people in the US since 2003. The team uses data from a large national study that involves interviewing and assessing the health of a nationally representative group of about 5000 individuals annually.

Volunteers describe their eating habits, or those of their young children, in face-to-face interviews. Snacks or meals described as "restaurant fast food" or "pizza" were classified as fast food.

Data collected between 2015 and 2018 revealed that, on average, young people aged between 2 and 19 got about 14 per cent of their daily calories from fast food. Only 11 per cent of young people obtained less than 25 per cent of their daily calories from such meals. Between 2009 and 2010, children obtained just under 11 per cent of their daily calories from it.

Fast-food consumption could have lasting health impacts. Studies suggest that children who eat more fast food have more fat and sugar in their diets and are more likely to put on fat, putting them at greater risk of obesity in adulthood. **Jessica Hamzelou**

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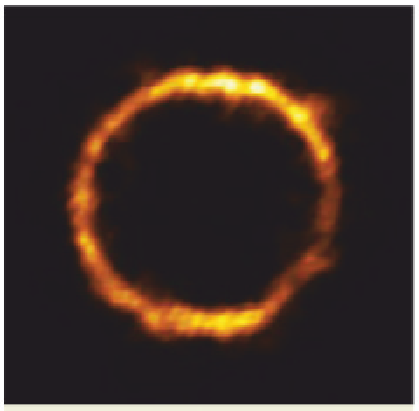
ALMA (ESO/NAOJ/NRAO), RIZZO ET AL.

Ancient galaxy is eerily peaceful

A galaxy known as SPT-SJ041839-4751.9 is so far away that we see it as it existed when the universe – now some 13.8 billion years old – was just 1.4 billion years old. Such early galaxies are predicted to have been turbulent, but this one is serene, testing our ideas of how early galaxies formed (*Nature*, doi.org/d6nh).

Male frog stays loyal to two females

The genetics of the tadpoles of *Thorapa taophora* frogs in the Brazilian rainforest suggests that males stay faithful to two females throughout the breeding season. This mating style, known as single-male polygyny with fidelity, has never been seen in amphibians before (*Science Advances*, doi.org/d6ng).

Cremation began in the Stone Age

An excavation in Israel has uncovered the oldest known evidence of cremation in the region. The 9000-year-old remains might hint that Stone Age people were beginning to change their religious beliefs, reducing the emphasis on worshipping ancestors (*PLoS One*, doi.org/d6nf).

Palaeontology

Trilobites had eyes like modern insects

AN ANIMAL that lived 429 million years ago had compound eyes similar to those of insects like bees and dragonflies. This implies that the compound eye evolved early in the history of animals.

"I am quite sure that its roots lie far back in the Precambrian," says Brigitte Schoenemann at the University of Cologne in Germany. The Cambrian period, when many major animal groups appeared, began about 540 million years ago.

With Euan Clarkson at the University of Edinburgh, UK, Schoenemann examined fossils of a 1.2-centimetre-long animal called *Aulacopleura koninckii*. It was a trilobite: a marine animal a bit like a woodlouse.

Trilobites dominated the oceans for 300 million years, beginning about 520 million years ago, and studying them offers clues to the origins of related groups like insects and crustaceans.

Schoenemann and Clarkson found that one *A. koninckii* specimen still had its left eye. It was a compound eye, which contains many tiny receptors called ommatidia, each with light-sensitive cells and a lens to focus light. Each ommatidium contributes a single "pixel" to create a mosaic-like image.

The structures of its ommatidia were almost identical to those of modern insects. The only difference was that they weren't quite as densely packed, probably reducing the detail that the animal could see (*Scientific Reports*, doi.org/d6m7). But to all intents and purposes, it was a modern compound eye, says Schoenemann. **Michael Marshall**

Insects

INGO ARNDT/MINDEN/NATUREPICTUREPL.COM

Chemical that spurs locusts to swarm could also stop them

A CHEMICAL released by locusts encourages them to swarm. This discovery could help us prevent the insects destroying swathes of crops.

Locusts normally live solitary lives, but can undergo a physical change that makes them become gregarious and gather in huge swarms. Most control methods rely on spraying swarms with insecticide, which also harms other organisms.

Le Kang at the Institute of Zoology in Beijing, China, and his colleagues investigated 35 volatile chemicals that are emitted in greater quantities by gregarious migratory locusts (*Locusta migratoria*) then by solitary ones. This widespread species is found in Africa, Asia, Australia and New Zealand.

Gregarious locusts seemed to prefer one chemical in particular, called 4-vinylanisole, and when the team overcrowded solitary locusts by placing groups of 30 in small cages, the insects began emitting it within 24 hours (*Nature*, doi.org/gg7vqk).

The locusts were drawn to sticky traps baited with 4-vinylanisole and the team suggests the traps could be used to attract locusts to a small area, which could then be sprayed with insecticide in a targeted way. MM

Anthropology

Earliest known beds made of grass and ash

PEOPLE living in a cave in southern Africa slept on grass bedding 227,000 years ago – by far the oldest discovery of its kind.

Lyn Wadley at the University of the Witwatersrand in Johannesburg, South Africa, and her team have been excavating Border cave in South Africa, which was inhabited in prehistoric times. The peoples living there left many layers of deposits that have been preserved by the dry conditions.

The team found grass bedding in many of the layers, made from species including *Panicum maximum*, which still grows outside the cave. The oldest layers containing bedding are between 227,000 and 183,000 years old.

The bedding was often on top of ash layers. In some places, the ashes are of burned grasses, suggesting people burned old bedding and placed new grass on top. In others, the ashes are of burned wood, suggesting ashes from fires were spread out and grass placed on top (*Science*, DOI: 10.1126/science.abc7239).

The team also found burned camphor wood – camphor is still used as an insect repellent today. "Maybe it was burned for the smoke it creates that would repel flying insects," says Wadley. **MLP**

Welcome to our Signal Boost project – a weekly page for charitable organisations to get their message out to a global audience, free of charge. Today, a message from **Worldwide Cancer Research**

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cancer
research

worldwide
cancer
research
emergency
appeal

Starting cancer cures for 40 years. But then COVID-19 struck

Worldwide Cancer Research starts cancer cures in the UK and the rest of the world. Each year, the charity commits £4million to the best researchers. Since the charity was founded in 1979, it has funded £200million of research in over 30 countries.

Devastatingly, cancer research has been delayed and put on hold since the beginning of the outbreak. Delays which could mean the difference between life and death for cancer patients who urgently need new treatment options.

A positive from the pandemic however is that scientific research is back in the spotlight. Now, more than ever, people are seeing the power of research – to solve problems, to save lives and, crucially, to develop treatments. Imagine if we could do the same for cancer?

There are around 1,000 new cancer cases every day in the UK. Whilst the long-term consequences of putting cancer research on hold might not be visible yet, that does not mean they are not there. Science is a global effort, so as we start to reimagine the "new normal", cancer research needs to be at the top of the agenda – not just in the UK, but around the world.

Whilst the pandemic is tearing us apart, Worldwide Cancer Research knows that it will be research that will bring us all back together. But, since lockdown began, much of the charity's fundraising has had to stop and its lifesaving research is at risk. Yet, cancer carries on.

Will COVID-19 cause a shift in focus from discovery research to translational research? Will the limited amount of funding impact the future generation of scientists? Or worse – will the instability of the global economy see less money being dedicated to life-saving cancer research? The charity seeks to answer these questions – and more. But it needs your help.

We cannot lose sight of new cancer cures; people with cancer around the world need support more than ever before.

Want to help?

You can give people with cancer hope by supporting the charity's emergency appeal. Your kindness today will help start new cancer cures tomorrow.

Visit worldwidecancerresearch.org/donate

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Graham Lawton wants us to rewild the sky **p24**

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Another good reason for universal mask wearing? **p26**

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Surf's up again on the beaches by Fukushima **p28**

Culture
Understanding our place in the human family tree **p32**

Culture columnist
Sally Adee grapples with Stephen Baxter's *World Engines* **p34**

Comment

How to stop pandemics

We should start using genetic techniques to prevent animal diseases spilling over into humans, say **Scott Nuismer** and **James Bull**

MICHELLE D'URBANO

A FAMOUS quote often attributed to Benjamin Franklin is "an ounce of prevention is worth a pound of cure". The world is now discovering the cost of its pound of cure for covid-19. But what would an ounce of prevention look like?

For infectious diseases that originate in wild animals, like covid-19, SARS, MERS and Ebola, one solution is to prevent the transmission to humans in the first place. To achieve this, an important first step is to change our behaviour to reduce contact with the wildlife species that harbour such diseases.

A complementary approach is to target the infectious agents that carry these diseases by reducing their prevalence or eliminating them within wildlife populations. Although this isn't a new idea, advances in technology mean we may have a better chance of it succeeding than ever before.

The classic example of this is rabies: we vaccinate dogs and many wild carnivores to suppress rabies in those populations and so reduce our own risk of catching it. Although these vaccination campaigns have virtually eliminated human rabies in the US and Europe, the disease still kills more than 55,000 people annually across Africa and Asia, where the cost of wildlife vaccination projects is a barrier to maintaining a sufficient level of immunity.

Using wildlife vaccination to target other dangerous pathogens that circulate within bats and rodents – such as Ebola, Marburg, SARS and Lassa viruses – faces similar obstacles, which is compounded by the rapid population turnover and large population sizes of these animals.

A possible solution is to create vaccines that spread themselves through an animal population.

These "self-disseminating vaccines" can be developed in at least two ways. The conventional approach relies on applying a vaccine to the fur of captured animals and releasing them. When these animals return to their natural homes, social grooming results in the vaccine being ingested by other individuals, magnifying the level of immunity that can be achieved.

This shows promise for reducing the threat of rabies transmitted to humans from vampire bats, for example.

A more radical approach relies on inserting a small piece of the genome of the infectious disease agent into a benign virus that spreads naturally through the animal population. As this transmissible vaccine spreads from animal to animal, it immunises them against the target infectious disease, vastly increasing immunity within the animal population and reducing the risk of spillover to humans.

The technology for developing transmissible vaccines now exists, and field trials focused on protecting wild rabbits from a viral haemorrhagic fever using this technique have showed promising results. Efforts are now under way to develop prototypes for several important human pathogens, such as the Lassa and Ebola viruses.

Self-disseminating vaccines could be a revolutionary technology for reducing the threat of human infectious diseases that jump to us from wild animals. In addition to making wildlife vaccination feasible and cost-effective, this technology reduces the motivation to cull or exterminate ecologically important disease reservoir species, such as bats.

However, there is still much work to do. Lab and field trials need to check how effective this approach is and look for possible unexpected consequences of self-disseminating vaccines. But as the costs of our ongoing attempts to find a "cure" for covid-19 continue to accumulate, an ounce of prevention seems to be a better investment with each passing day. ▮

Scott Nuismer and James Bull are based at the University of Idaho

No planet B

Rewilding the sky

We should take inspiration from the way we intervene to help degraded ecosystems recover and attempt to restore the atmosphere to its former glory, writes **Graham Lawton**

Graham Lawton is a staff writer at *New Scientist* and author of *This Book Could Save Your Life*. You can follow him @grahamlawton

IN A parallel universe, I have just returned from a gathering in Salt Lake City, Utah. The Ecological Society of America's annual meeting was a hive of activity: 4000 delegates, talks on cutting-edge research, press conferences, social gatherings and ample opportunities to mingle, make contacts and pick up ideas.

In the real world, the meeting was held virtually and I watched it at home on my computer. I take my hat off to the organisers and speakers; in the circumstances, it was amazing. But it wasn't the same as the real thing. I wonder what chilling effect it might have had on that precious currency of scientific progress, the exchange of ideas over a couple of drinks.

Much has been made of the fact that, before the pandemic, we massively overestimated the need to be physically present to get things done. I have been working productively from home and have burned a lot less oil going to international gatherings, while actually attending more than usual. I have repeatedly heard people extol the virtues of these virtual meetings, and I agree there is a lot to be said for them: people from all over the world can get together at the click of a mouse. Teleworking has contributed to the decline in emissions during the pandemic.

But let's not get carried away. Another meeting was a webinar with Fatih Birol, the executive director of the International Energy Agency. Organised by University College London, it was a great example of the use of technology to keep international scholarship alive. Birol's theme was a now-familiar one: how to leverage the anthropause – the lull in human activity under covid-19 – to bring about a decisive shift in the world's energy economy. A lot of ink has already been spilled enthusing about this idea. Birol is optimistic that we can solve our environmental problems, but he is a hard-headed, data-driven realist.

He made it clear that work-related lifestyle changes are just a smidgen of what we need. "I don't think through webinars and through Zoom meetings we can solve the world's energy and climate problems," Birol said. "Today, according to our numbers, only 10 per cent, maximum, of the labour force can work from home. Aviation is only 7 per cent of global oil consumption."

> **"We shouldn't merely aim to halt the atmosphere's destruction, but to nurse it back to full, pristine health"**

For now, meetings like the Ecological Society of America have to be virtual to keep everybody safe, but for the sake of scientific progress I think they will eventually revert back to the old face-to-face normal. That isn't to say that the meeting was a write-off. Far from it. In fact, a lecture by another international mover and shaker, ecologist Rob Jackson of Stanford University in California, was one of the most inspirational I have sort-of attended since I began working from home in March.

Jackson's theme was restoring the atmosphere, by which he means returning it to its pre-industrial state. Jackson said he was no longer satisfied with goals to keep warming to 1.5°C or some other arbitrary value, but longed to return the atmosphere to how it was before we started dumping carbon dioxide, methane and other pollutants into it.

Taking inspiration from the growing field of ecological restoration – intervening to help degraded ecosystems recover – he argued that we should treat the atmosphere as we do wetlands, forests or endangered species. We don't merely aim to halt their destruction, but to nurse them back to full, pristine health. The atmosphere deserves no less. Think of it as rewilding the sky.

Yes, he admitted, it seems a "preposterous idea". We can't even stabilise levels of greenhouse gases, let alone reverse them. But, he said, with so much bad news we need a new narrative of hope. Temperature thresholds are abstract; normal people don't relate to them. "They don't provide a narrative that has, or will, lead to action."

The roadmap to atmospheric restoration is largely familiar: renewable energy, a trillion trees, carbon capture and storage and negative emissions technology. But one step is something I'd never heard of before: sucking methane directly out of the atmosphere.

The technology to do this is in development, and compared with CO_2 removal it should be easy. The thermodynamics are favourable, as methane is more energy-rich than CO_2. There is less methane to get rid of, but it has an outsized effect: about a third of warming so far is attributable to it. Removing 3.2 billion of the 5.6 billion tonnes of this gas would restore methane levels to pre-industrial levels and it would have knock-on benefits as methane plays a role in ozone pollution in towns and cities.

When Jackson first mentioned atmospheric restoration, I thought it was pie in the sky. Now I'm warming to it and can't wait to fly to the US to hear about progress at the next annual meeting in Long Beach, California, in August 2021. I promise to offset my emissions. ■

Graham's week

What I'm reading

Foucault's Pendulum *by Umberto Eco. I read it years ago, but it seems even more relevant now.*

What I'm watching

Once Upon A Time In Iraq *on the BBC, the most amazing documentary series I've seen in a long time.*

What I'm working on

Winding down for a plan B holiday. Fingers crossed for the British weather!

This column appears monthly. Up next week: Annalee Newitz

New Scientist
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Hundreds of new studies about our physical and mental well-being are published every week, but the results can be conflicting and confusing. Our monthly newsletter gives you the health and fitness news you can really trust – which, amid the coronavirus pandemic, is more important now than ever.

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Clare Wilson

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Editor's pick

Another good reason for universal mask wearing?

8 August, p 10

From Francis Banks, Loulé, Portugal

Reading "How to stop superspreaders" reminded me of an experience I had the other day when at lunch with a friend. Although elderly, he refuses to wear a mask – but, of course, you can't wear a mask when eating anyway.

I suddenly noticed a cooling effect on my skin when my friend was speaking, even though he was sitting a good metre away. I realised that – at that moment, at least – he was a "sprayer", projecting saliva as he spoke. Some people I have met do this whenever they speak. Could they be among the superspreaders?

From Dave Neale, Truro, Cornwall, UK

Your article raises more questions than the title suggests. Every test and trace case should provide valuable information about the spread of the virus. How did person A contract it? How did they pass it on to person B? And why didn't they infect persons C, D and E, with whom they were also in contact?

Statistical evidence from just a few days in any one country should give us incredibly useful data about how the virus is spreading. Yet our knowledge seems to be confined to a relatively small number of cases. Am I missing something or is test and trace just a mirage?

Why some people may be reluctant to toe the line

8 August, p 8

From Hillary Shaw, Newport, Shropshire, UK

Why is mask wearing so divisive? Maybe because we are connected in large communities and must trade some personal freedom for the benefits of cooperation. Some of us highly value what we gain from this and will sacrifice more freedom. We forgo comforts and conveniences to save the environment, modify our behaviour to avoid annoying our neighbours, give up wealth to help the less fortunate and wear masks to protect others from covid-19.

Others value personal freedom above such benefits and make the opposite trade-offs. Maybe mask-resisters tend to recycle less and drive large cars?

Perhaps the majority were right after all

1 August, p 46

From Allan Jones, Yardley Gobion, Northamptonshire, UK

Your promotional piece for *The Brain: A user's guide* refers to the "better-than-average effect", or "the statistically impossible effect in which the majority of people rate themselves more favourably than average".

Assuming average here means the mean rather than the median, it isn't impossible for a majority to be above or below it. This depends on the distribution. For example, the majority of people have more legs than the mean number of legs per person.

The editor writes

The Brain: A user's guide, a *New Scientist* compilation, is on sale now.

A possible reason for the X chromosome conundrum

1 August, p 42

From Chris Hall, Reading, Berkshire, UK

Sharon Moalem's explanation for differences in life expectancy between men and women raises another question. Why has natural selection led to the X chromosome being the location for so many genes related to our immune system? Why aren't they on chromosomes 1 to 22, where both men and women will have two active versions of each gene?

Perhaps there is a reason. When a new, deadly pathogen emerges, the immune system needs to act fast. Suppose there is just one active version of an immune gene that gives protection. If it is on any of chromosomes 1 to 22, the death rates of men and women will be equally high and half of children will inherit the protective gene.

If it is on the X chromosome, men will die out at a greater rate than women, but those surviving will probably have more children. For these men, the critical gene will be on their X chromosome, which they will pass on to all their daughters, while women will pass it on to only 50 per cent of daughters and sons. Overall, resistance to the pathogen in the population will be accelerated.

Weird rings could be like space rainbows

11 July, p 14

From Ben Haller, Ithaca, New York, US

You report that "odd radio circles", or ORCs, have been detected. They are "symmetrical and their edges are brighter than their interiors". I know nothing about radio astronomy, but I can tell you what that description reminds me of: a rainbow. Of course, I am not suggesting that reflection inside water droplets is responsible, but perhaps some analogous process might be. If so, the original source would be in the opposite direction from the ORC, as seen from Earth.

The cosmos may only have meaning because of us

1 August, p 24

From Eric Kvaalen, Les Essarts-le-Roi, France

In her review of *The End of Everything*, Leah Crane writes: "What all the endings have in common is to highlight the vastness of the universe, and the banality of our everyday existence."

I think it is our existence that gives meaning to the universe. Without us, it is just a machine grinding on and on. Perhaps when we have all gone on to another world of consciousness, this "universe" will no longer be real, will no longer exist. Maybe that is its end.

Zeroing in on the best spot for the origin of life

8 August, p 34

From Michael Paine, Sydney, Australia

You report suggestions that life may have originated in hydrothermal systems on land. This brings to mind earlier research by Pascal Lee and Gordon Osinski, who, among others, have studied the hydrothermal systems at the Haughton impact crater in the Canadian Arctic archipelago. Hydrothermal systems are usually formed in these asteroid impact craters. The asteroid also brings some raw ingredients for life.

So it is possible that researchers John Sutherland and David Deamer may have been talking about the same situation when you reported the following: "Sutherland has developed a scenario involving streams of water running down a meteorite impact crater. Deamer favours geothermal ponds in volcanic settings and is focusing research on these."

The speed of light spoils the black hole party

1 August, p 30

From Barry Isaacs, Tavistock, Devon, UK

The front cover, flagging up the feature on discoveries resulting from the first direct image of a black hole in a galaxy that is about 55 million light years away, should have read: "Last year we saw our first black hole. Now we know it will be seeing us too (in about 55 million years)".

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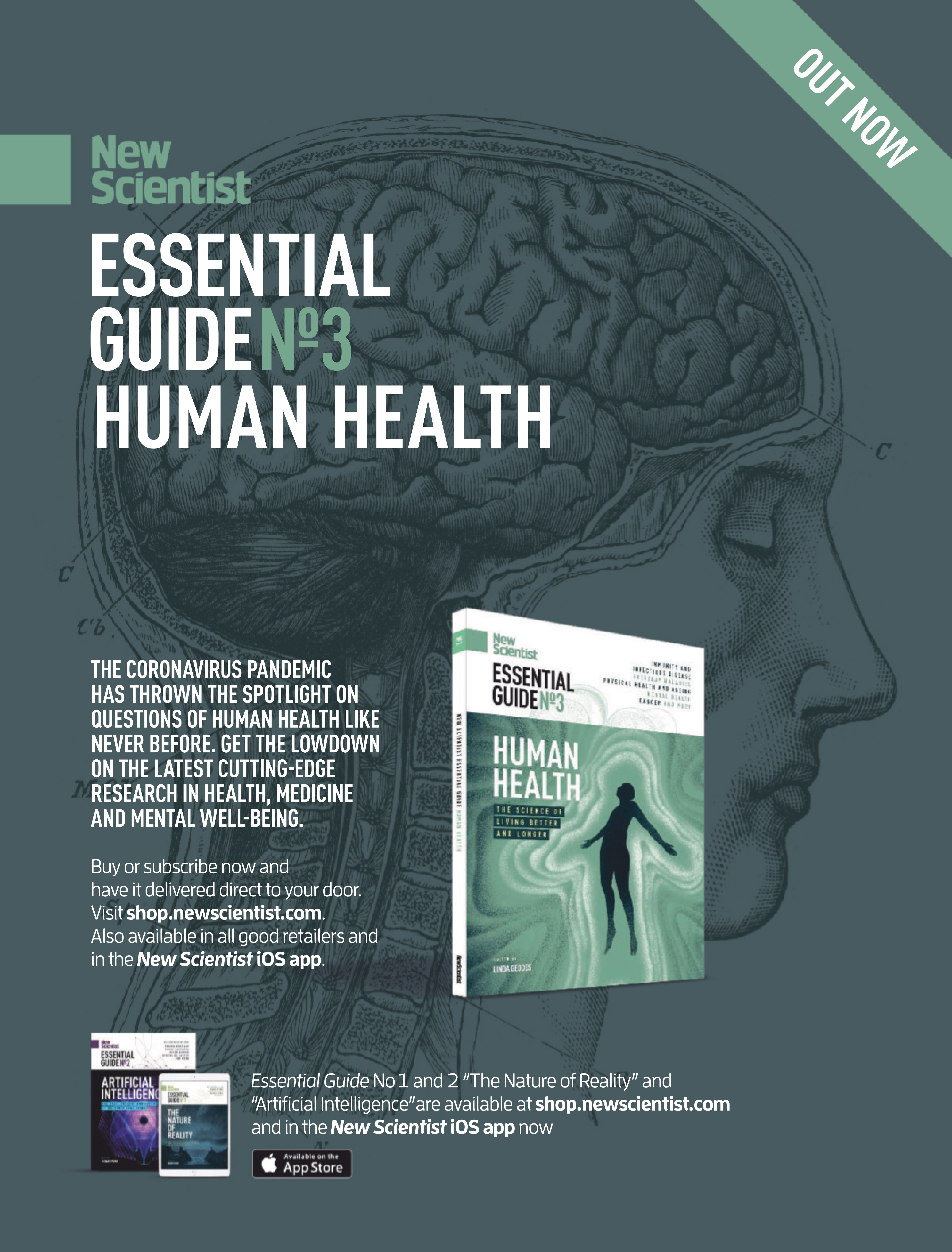
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Troubled waters

Photographer Laura Liverani
Agency Prospekt Photographers

THIS surfer is one of many hoping to catch the waves at Kitaizumi beach in Japan's Fukushima prefecture. The coastal spot was once hailed as a surfer's paradise thanks to its high waves and sandy shores. Yet it has been almost a decade since it has been able to enjoy that status.

In 2011, the Fukushima Daiichi nuclear power plant – situated around 25 kilometres from the beach – was the site of the worst nuclear accident since the Chernobyl disaster in 1986, after it was hit by a devastating tsunami. Kitaizumi reopened to the public in 2019 after a huge decontamination effort, and surfers are keen to see people return to the beach.

Taken by photographer Laura Liverani as part of a series called *Fukushima Surfers*, the image shows how the sport is making a comeback in the area. Though the building in the background is the Haramachi coal power station, not Fukushima Daiichi, the legacy of the nuclear plant still lingers.

Due to a lack of space, Japan plans to tip 1 million tonnes of contaminated water stored from the disaster – a combination of recovered groundwater and deliberately injected cooling waters – into the Pacific Ocean after it is treated. Managed properly, this shouldn't release any harmful radioactive particles that could pass into marine sediment and fish or threaten surfers' safe return to the sea. ▮

Gege Li

Engineering in a post-pandemic world

The challenge is to rebuild our battered economy. *New Scientist* asked a panel of experts how the engineering community should respond

Earlier this year, as coronavirus tightened its grip on the UK, fears grew that the NHS would be overwhelmed by a lack of personal protective equipment (PPE) for workers and a shortfall in ventilators for the severely ill. Britain's engineering community stepped into the breach. In just three months, it designed and built almost 14,000 ventilators and produced countless protective devices.

The urgency of the task forced engineers to accelerate their learning cycle. The community scaled up the production of three types of ventilators and developed a new model that it guided through regulatory approval in 21 days. At the same time, the community faced and overcame huge procurement challenges while training thousands of workers to produce the designs.

"The Ventilator Challenge has proven just how much Britain can achieve when confronted with a difficult problem - bringing together the best minds in manufacturing, innovation and design," said Britain's prime minister Boris Johnson.

But the challenge is not yet over. As Britain emerges from lockdown, a new world order is developing with profound implications for the way we live and work. At issue is how to re-vitalise the economy with the same spirit of innovation that emerged during the Ventilator Challenge. At the same time, the economic reboot offers a unique opportunity to create a lower carbon society.

These challenges raise profound questions for the engineering community. Earlier this month, New Scientist, in association with BAE Systems, organised an online debate with a panel of experts to discuss the future of engineering in this post-covid world.

The backdrop to the discussion makes grim reading. By early August, the human toll had reached 690,000 deaths worldwide, more than 46,000 of them in the UK. The economic toll was also dire. Between April and June, the UK's GDP fell by 20 per cent, the biggest drop ever recorded in this country. In response, the UK government spent billions to secure the economy but questions remain over how Britain will bounce back.

Certainly, the virus has changed the way we work. Almost overnight, the UK became a nation of remote workers, a change that looks to be permanent. "We're never going to go back to the rigidity of what working hours and days look like," said Hayaatun Sillem, chief executive of the Royal Academy of Engineering and a member of the panel.

She points out that this improves flexibility and accessibility for many people—working parents and those who are disabled, for example. "That's a good thing from the perspective of diversity and inclusion," she said. But she also warned of the toll this has taken on mental health.

Spirit of innovation

While some engineers worry about gauging the mood of their team via video calls, others have found it a boon. "I've found it marvellous to have 10 people up on a screen. I can see who's happy and who's not immediately - in fact it's a lot easier than when I'm sitting in a room," said panel member Alec Broers, a cross-bench member of the House of Lords and chair of the All Party Parliamentary Engineering Group.

But collaborating to come up with new solutions – an essential part of engineering – can be more difficult remotely, says Dave Short, technology director at BAE Systems and a panel member. "I think actually that natural human interaction does work better in terms of problem solving when there is emotional interaction around a table."

Remote working also raises questions of online security, as all companies need to protect information, particularly those involved in defence. The issues associated with the Chinese company Huawei's involvement in the UK's 5G network, compound this problem.

Nevertheless, the panel agreed that core engineering skills will play an important role in any recovery. "We still have really strong demand for engineering skills and new skills coming through, such as in AI and some specialist types of mathematics," said Short, adding that his employer is recruiting 800 apprentices this year.

The pandemic required large companies, like BAE Systems, to act with unprecedented speed to support ventilator production and turn their industrial 3D printers to the production of PPE. Acting like a startup has been a valuable lesson for Short. He says big

METAMORWORKS/ISTOCK PHOTO

> “We’ve proved to ourselves that we can undergo more radical transformation than we ever felt possible”

The Future of Engineering panel (clockwise from top left): Lord Alec Broers, Chair of the All Party Parliamentary Engineering Group; Dr Hayaatun Sillem, Chief Executive of the Royal Academy of Engineering; Justin Mullins, consultant editor at *New Scientist* and debate chair; Dave Short, Technology Director at BAE Systems

companies should exploit SME-style innovation by using their size and capability to accelerate it.

That will require investment and the role of government in planning for the future will be crucial. For example, the panel discussed how a technology roadmap would give companies the confidence to invest in research and development. Short agreed that a long-term plan would bring greater opportunities for investment in engineering and the chance to capitalise on the country’s newfound innovative spirit. “Let’s not let it wither, let’s capitalise on it,” he said.

Incentivising investment is important, agreed Sillem, warning that cash flow is an issue and research spending is one of the easiest things for companies to cut . The panel agreed that companies that continue to invest in R&D will be more agile and resilient in the face of future challenges.

One of the most important of these challenges is to create a low carbon future. At the peak of the confinement measures in early April, daily carbon emissions decreased by 17 per cent globally, providing a tantalising glimpse of a lower carbon world. Indeed, the UK is committed to net zero greenhouse gas emissions by 2050.

But the engineering systems challenge is enormous, requiring a transformation of infrastructure systems from transport to energy, and the development of new technologies. Sillem believes the pandemic may help leaders tackle this daunting task. “We’ve proved to ourselves that we can undergo more radical transformation than we ever felt possible, at the pace we have done, because we’ve had no choice,” she said. “We have to carry on that ambition into how we tackle our green recovery.”

The panel’s views resonate with a recent Ipsos MORI poll for King’s College London, suggesting two thirds of people in the UK think the pandemic is a chance to build a better country.

In many ways, the engineering community has set the tone for this ambition. “I think the UK has done a fantastic job. The time restriction and acute need [for ventilators and PPE] inspired engineers to create new ways of working and allowed some processes to be streamlined,” says Short. “We need to take those lessons forward with innovative approaches where we can break out into the new world order.”

Watch the New Scientist Debate on the Future of Engineering at: https://bit.ly/394gkZO

New Scientist events

Who were the Neanderthals?

Hear Rebecca Wragg Sykes talk about our ancient cousins

For details about this virtual event visit newscientist.com/events

Hominin history

Modern techniques are helping us to better understand Neanderthals, as well as where we fit in to the family tree, finds **Simon Ings**

Book

Kindred: Neanderthal life, love, death and art

Rebecca Wragg Sykes

Bloomsbury Sigma

JORGE GUERRERO/AFP VIA GETTY IMAGES

Neanderthal art in Spain, painted between 43,000 and 65,000 years ago

HOW we began to unpick our species' ancient past in the late 19th century is an astounding story, but not always a pretty one. As well as attaining tremendous insights into the age of Earth and how life evolved, scholars also entertained astonishingly bad ideas about superiority.

Some of these continue today. Why do we assume that Neanderthals, who flourished for 400,000 years, were somehow inferior to *Homo sapiens* or less fit to survive?

In *Kindred*, a history of our understanding of Neanderthals, Rebecca Wragg Sykes separates perfectly valid and reasonable questions – for example, "why aren't Neanderthals around any more?" – from the thinking that casts our ancient relatives as "dullard losers on a withered branch of the family tree".

As an archaeologist with a special interest in the cognitive aspects of stone tool technologies, Wragg Sykes paints a fascinating picture of a field transformed almost beyond recognition over the past 30 years.

Artefacts at well-preserved sites are no longer merely dug and brushed: they are scanned. High-powered optical microscopes pick out slice and chop marks, electron beams trace the cross-sections of scratches at the nano-scale and rapid collagen identification techniques can determine an animal from even tiny bone fragments.

The risk with any new tool is that, in our excitement, we over-interpret the results it throws up. For example, while Neanderthals may have performed some funerary activity, they may not have thrown flowers on their loved ones' graves as we once thought.

Other stories continue to accumulate a weight of circumstantial evidence. We have known for a few years that some Neanderthals tanned leather; now it seems they may also have spun thread.

> "The significance of Neanderthal art may simply be that Neanderthals had fun making it"

An exciting aspect of this book is the way it refreshes our ideas about our own place in hominin evolution.

Rather than congratulating other species when they behave like us, Wragg Sykes shows that it is much more fruitful to see how human talents are related to behaviours exhibited by other species.

Take art. We tend to ask questions like: were the circular stone assemblies discovered in a cave near Bruniquel in southern France in 2016 meant by their Neanderthal creators as monuments? What is the significance of the Neanderthal handprints and ladder designs painted on the walls of three caves in Spain?

In both cases, we would be asking the wrong questions, says Sykes. While striking, Neanderthal art "might not be a massive cognitive leap for hominins who probably already understood the idea of representation".

Animal footprints are effectively symbols and tracking prey this way "requires an 'idealised' form to be kept in mind", she writes.

Human infants, given painting materials, enjoy colouring and marking surfaces, though they aren't in the least bit invested in the end result of their labours. The same is also true of captive chimpanzees. Why, then, should we see Neanderthal art with any significance, beyond the possibility that Neanderthals had fun making it?

Neanderthal DNA contains glimmers of encounters between them and other hominin species. Recent research suggests that interbreeding between Neanderthals and Denisovans, as well as Neanderthals and *Homo sapiens*, was effectively the norm. Like modern cattle and yaks, we were closely related species that varied in bodies and behaviours, yet could also reproduce.

Neanderthals were part of our family, and though we carry some part of them inside us, we will never see their like again. ▮

Against the current

Tesla is a creative and imaginative biopic, but it does a better job with Thomas Edison than its lead subject, says **Bethan Ackerley**

Film

Tesla

Michael Almereyda

Out 21 August

TO MANY, Nikola Tesla is a folk hero. He is a steady fixture in science fiction, and his role in the war over whether alternating or direct current should be used to transmit electricity in the late 19th century has cemented him in the popular imagination as a slayer of giants. Take that, Thomas Edison.

In *Tesla*, director Michael Almereyda makes hay out of that war and other events from the visionary inventor's life, but not without including a few fantastical turns of his own.

The film begins with Tesla (Ethan Hawke) working at Edison Machine Works, where he butts heads with his employer over funding. Edison (Kyle MacLachlan) is bullish and xenophobic, asking Tesla, who was born in what is now Croatia, if he has ever eaten human flesh.

The depictions of Edison's attempts to discredit alternating current, from using it to kill animals in public demonstrations to the botched electrocution of a prisoner, is well-trodden ground for people familiar with his ruthlessness.

Yet the film achieves more nuance in its brief flashes of Edison's personal life than it ever does with Tesla's. A biopic that leaves you more interested in the subject's rival has gone wrong somewhere.

Part of this failure comes from the moments that the film prioritises. Tesla's poverty after leaving Edison's firm and being swindled by his own business partners is mentioned only briefly, for instance, in favour of repetitive demonstrations of his induction motor that have none of the visual dynamism such a revolutionary invention deserves. "No sparks," one observer notes.

The story is periodically interrupted by Anne Morgan (Eve Hewson), the daughter of one of Edison's principal investors, who sits with a laptop and offers up pithy, fourth-wall-breaking context.

> "Tesla's poverty after leaving Edison's firm and being swindled is mentioned only briefly"

The film is also peppered with farcical metaphors, including ice-cream fights, rollerblading accidents and even an anachronistic rendition of *Everybody Wants To Rule The World*.

While these choices confuse as often as they delight, it is fitting for a Tesla biopic to take risks and display such imagination. One poignant scene asks us to envisage a world in which Edison apologises to Tesla and suggests a partnership. What could Tesla have achieved with the commercial guidance of "an enlightened hustler" like Edison?

Hawke plays Tesla as a morose workaholic, bristling with social discomfort. Though there is a degree of truth in that portrayal, Tesla was reportedly well-liked when he did socialise and had a variety of interests, with one contemporary describing him as "a poet, a philosopher, an appreciator of fine music, a linguist, and a connoisseur of food and drink".

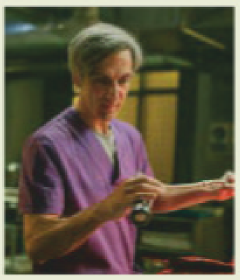
Such qualities are barely touched on, save for a sequence in which he is deeply moved by actress Sarah Bernhardt (Rebecca Dayan), who becomes a figure of fascination. It is in his interactions with her that Hawke is finally given something to do; Bernhardt witnesses Tesla's humiliation at the hands of Edison and the shame breaks through his taciturn shell.

Ultimately, the film rarely finds the will to be interested in the man Tesla actually was. Coupled with its incoherent – if striking – aesthetic, this means *Tesla* too often feels like an empty frame, or a motor without the power to keep it running. ▮

COURTESY OF IFC FILMS

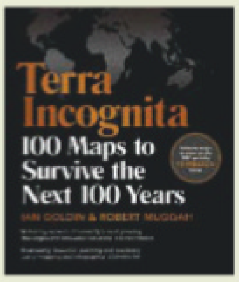
Tesla leaves you more interested in Thomas Edison (Kyle MacLachlan)

Don't miss



Watch

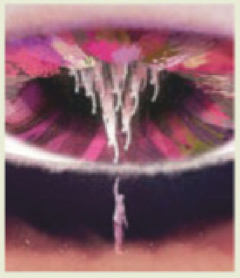
Unknown Origins sees a murderer recreate superhero origin stories in an entertaining caper set in Madrid. During production, comic fans mobbed its comic-book store set, thinking it was real. On Netflix from 28 August.



Terra Incognita
100 Maps to Survive the Next 100 Years
IAN GOLDIN & ROBERT MUGGAH

Read

Terra Incognita by Ian Goldin and Robert Muggah features "100 maps to survive the next 100 years", showing how people, cities, wars, climates and technology are changing Earth.



Listen

Invisibilia tells sumptuously produced tales of scientific wonder as Alix Spiegel and Hanna Rosin explore the hidden forces shaping our behaviours, ideas and beliefs in this NPR podcast.

NETFLIX; LEONARDO SANTAMARIA FOR NPR

The sci-fi column

Our place in the multiverse

Stephen Baxter's *World Engines* series examines whether humanity can get off this planet without destroying the universe – or, at least, not every universe. It is gripping but frustrating, says Sally Adee

Sally Adee is a technology and science writer based in London. Follow her on Twitter @sally_adee

GORODENKOFF/GETTY IMAGES

Why do we risk so much in the hope of colonising space?

Book series

World Engines

Stephen Baxter

Gollancz

REID MALENFANT wakes up from a cryogenic coma in the year 2469. It was 2019 when he crashed a space shuttle and entered medical deep freeze, just as Earth's citizens were taking their first steps to colonise the solar system. The world he wakes in 450 years later is unrecognisable. We burned all our fossil fuels for the space race and the consequences are in full bloom: London, New York, Florida and many coastal areas are drowned, and the planet is tropical.

Those are just the cosmetic changes in *World Engines: Destroyer*, the first in Stephen Baxter's series. The human project has ended – we retreated from the solar system, recognising our inability to thrive outside our biosphere. We retreated on Earth too, with a population fallen below 100 million, both as a result of centuries-long destruction and as a way to let nature heal.

As Malenfant digs deeper, though, he discovers another contributing factor. A solar system-rending cataclysm has been foreseen in about 1000 years, so Earth is in a period of managed decline. It isn't a bad existence for the people. There is no pollution and no waste, with every car, cup and plate made to last generations. Universal basic income (UBI) means no one is poor. People still have children. But there is no drive to do more than exist in this Eden.

Yet the 25th century woke up Malenfant for a reason, of course.

> **"In one universe, Richard Nixon created a *Star Trek*-like programme that had boots on Mars by 2005"**

That reason takes him to the Martian moon Phobos, which has been displaying idiosyncracies that turn out to be a hatch to other universes. By the end of the first book, Malenfant has set out to discover who built the portal and what kind of entities play snooker with entire solar systems.

It is these questions that are addressed in the second book, *World Engines: Creator*, and their answers leave deeper questions about humanity's relentless obsession with expansion. What do we risk by embarking recklessly into the solar system, the universe or even the multiverse? What is this impulse to colonise? Are the only choices eternal expansion or managed decline?

Many readers may have given up on the first book after some 200 pages because of Malenfant, a jerk ripped straight from the pages of 1960s sci-fi at its most toxically masculine. But the clue is in the name. Soldier on and it is clear that Baxter has written Malenfant to reflect our current condition as a species: selfish, greedy and full of toxic individualism.

As Malenfant begins to evolve, the books hit their stride, asking questions that telescope out into brain-exploding territory. Baxter has an encyclopedic knowledge of early space and military history that he remixes into delightful mash-ups. In one universe, instead of sinking in the Watergate scandal, US president Richard Nixon set up UBI, leading the world to follow suit – and to the creation of a *Star Trek*-like space programme that had boots on Mars by 2005.

In another, Winston Churchill is ousted by his opposition rival, Neville Chamberlain. This creates a British-led dominance of space in steampunk space behemoths, spreading diamond-cut accents and Victorian repression.

Other books have grappled with our place in the multiverse, but few have Baxter's vision and ability to work at very different scales. *World Engines: Creator* isn't always evenly paced, gets bogged down in science pedantry and can be exasperatingly opaque at times, but I am crossing my fingers for a third book. ■

Sally also recommends...

Books/Comic

The Space Between Worlds

Micaiah Johnson's stunning debut is impossible to put down. It nails the stakes of the multiverse and employs a beautiful character transformation arc.

The Number of the Beast

Robert A. Heinlein's book is the first and best in this genre.

Infinite Vacation

Nick Spencer's comic world puts alternate versions of you up for sale. You choose the version you prefer that day, but there is always a price.

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"We should expect scientists to be much more open, but also more boring"

Psychologist **Stuart Ritchie** reckons a deep and pervasive rot is undermining science. Far too often, failures in the system lead us to believe in fictions, he tells Graham Lawton

WHEN Stuart Ritchie was a graduate student in Edinburgh, UK, in 2011, he was involved in an incident that shook his faith in science. With two colleagues, he tried and failed to replicate a famous experiment on precognition, the ability to see the future. They sent their results to the journal that published the original research and received an immediate rejection on the grounds that the journal didn't accept studies that repeated previous experiments.

Ritchie remained a scientist – he is a psychologist at King's College London with a focus on studying human intelligence – but ever since that rejection, he has been on a crusade to air science's dirty laundry. His latest book is *Science Fictions*, in which he shows how, all too often, we can't rely on the facts that science provides.

Graham Lawton: The grand and scary claim of your book is that something is rotten in the kingdom of science.

Stuart Ritchie: Absolutely. We think of science as being this objective thing that tells us facts about the world and produces all these scientific papers, which are almost sacred things. But a lot of people don't see how the sausage is made. I think if they had more of an idea of how the process happens, they would question the truth status of those papers much more. In a lot of cases, the science is useless, not worth the paper it is written on.

ROCIO MONTOYA

You identify four main causes of rot.

First there's fraud, when people deliberately alter or make up results to try to get a paper published. That's rare, but not as rare as we would like to think. If you ask scientists whether they've committed fraud, only a very small number say yes. But something like 14 per cent will tell you that they think they know of an instance where a colleague has committed fraud.

That blurs into the second thing, which is bias. Everyone wants to change the world, so people are biased towards finding significant results. And that can make them see things that aren't there. They might make arbitrary changes to their statistical analysis – called p-hacking – to find the result they want. Drop a few participants here, change a number there and convince yourself that it's the right thing to do.

The third cause is unforced errors, like a typo in a spreadsheet that knocks the whole result off track. That is negligence.

The last category is hype, where scientists are pushed towards writing up their results as if they are much more exciting than they are. The way papers are written now often makes it sound as if the findings are going to revolutionise the way we think about things. But we're not making more groundbreaking discoveries than we used to. It's just that there's pressure on how we're supposed to write up science, and lots of media excitement.

If you put all those four together, it looks as if something is very rotten.

How did we let the rot set in?

It crept in due to a system of perverse incentives. There's huge pressure to publish papers and huge pressure to bring in grants – which is an incentive to publish papers

›

and apply for grants, but not an incentive to discover the truth. We focus far too much on rewarding people who have brought in big grants or published papers in prestigious journals, which isn't necessarily getting us what we want.

But there are checks and balances, like peer review, where independent experts vet papers before they are published...
It works in some cases, but it's nowhere near the filter it needs to be. Some of the worst papers ever went through the peer-review system of the world's best journals.

For instance, the system isn't set up in a way that peer reviewers can easily get raw data. It's absurd. The people who are supposed to be checking whether the analysis is correct rarely see the data that the claims are based on.

Reviewers are also often rushed. They themselves are busy scientists. Journals want there to be only a short time between articles being submitting and accepted, so peer reviewers are pushed towards accepting things really quickly. And journals only want to accept the flashiest and most exciting claims.

That's before you get into any personal vendettas that some peer reviewers have for one another. Even if the paper is anonymous, you can usually tell who wrote it. If it's your rival lab, maybe you'll give it a very harsh review.

Another check in the system is replication. But that seems to have gone wrong.
I remember being told when I was an undergrad that a paper should be written in such a way that anyone could replicate the experiment. But when people try and do that, often they can't even set the experiment up because the paper doesn't contain enough information. When they can replicate the experiment, they often find results that are different or not statistically significant.

Scientists are not being fully open or transparent. They can often be quite reluctant to give more details when someone comes along and says, "I want to replicate your work", because there's this culture of, "Oh, I know best how to do this experiment."

> "Scientific papers are seen as this almost sacred thing. But a lot of people don't know how the sausage is made"

How much published science isn't replicable?
In my own subject, psychology, replication was recognised as a major problem from about 2011. About 50 per cent of studies in the literature don't seem to be replicable.

That replication crisis spread into pretty much every subject that has been looked at. In most subjects, if you ask scientists, "Do you think the research is completely robust?", a huge proportion say no. But it's hard to put a number on it because almost nobody else has made a systematic attempt to replicate results. My guess would be that the picture is less bad in other subjects, but we don't know.

I think that is itself a demonstration of the problem. We are not clear what proportion of papers from biomedicine or chemistry or physics and so on would be replicated because replication is not incentivised. Going back and doing someone's experiment again, is, in most cases, not what the journal system and the university system want.

Is the replication crisis getting worse?
I think there's evidence that things are worse now than they were 30 years ago in terms of this obsession with publication. People who finish their PhDs now are expected to have some astonishingly high number of peer-reviewed publications, something like 19. A few years ago, you'd be expected to have five or six. The quality of the work inevitably has to suffer.

This a long-standing problem. Why write a book about it in 2020?
We've got to the point where we have a handle on the issues. We've also got a great deal of so-called meta science, the science of science. People have spent their entire careers running large replication attempts. So I thought it was a good time to summarise where we are.

A lot of it is still a bit ivory tower, discussed only within science. When we're communicating to the public, we just go back to "here's a new exciting paper that tells

PLAINPICTURE/KRISTA KELTANEN

Even the world's leading journals occasionally publish poor science

us this is true" rather than revealing how the process really works.

Why should people who aren't scientists care about this?

So much of what we do relies on science. So if the whole system is off, then that has major consequences. It couldn't be more clearly illustrated than with covid-19. All of the things I've talked about have come up in the pandemic: accusations of fraud, retractions from top journals, screwed-up statistical analyses, lack of data sharing, negligence. And it has put rocket boosters under hype.

Another lesson we've learned is the dangers of pushing science out too quickly. We've seen a huge upsurge in research about covid-19, but a lot of it is probably completely useless. It's kind of unbelievable. There couldn't be a better illustration of the need for change.

Also, a huge amount of taxpayers' money is wasted on useless science. It actually makes it harder to discover the truth in future because it muddies the picture.

What is at stake? If science just shrugs and carries on as normal, what will happen?

At the moment, people have a high degree of trust in science and I think that's justified to some degree, certainly compared with politicians. But if people keep publishing these hyped results which end up not actually delivering on the promise, trust in science will decline.

We see it already in nutrition research. I think most people don't take that seriously any more. I would hate to get into a situation where other sciences are in that same boat and research becomes a laughing stock.

Do you worry about giving ammunition to anti-science voices?

I do. I worry particularly about already politicised areas like climate change, vaccines and evolution. The last thing we want is to give climate deniers and creationists yet more reasons to be critical of science.

I'm critical of the way science is done, but I'm not critical of the idea that science is the best way we have of discovering how the world works, of making new things that improve the world for everyone. That is the whole reason that we must be sceptical and critical of it. I would be disappointed if people took this book as saying, "Well, we can just chuck away science." That's absolutely the opposite of what I'm trying to advocate.

How can we fix it?

I think the broad answer is scientists being more open and transparent about what they actually did in their research. But I don't think that's the only answer. Universities need to stop hiring people just on the basis of how many papers and citations they have and start rewarding a different kind of science: people who contribute data to the world, people who are part of large replication projects, people who are creating new tools to help other scientists do research more efficiently. Being a good scientific citizen, essentially.

Journals need to change the way they publish articles. They can incentivise people to preregister their work, so they've published their data analysis plan before they actually get to the analysis and can't do stuff like p-hacking.

Ultimately, I feel like this is an optimistic book, even though it is essentially a litany of human failure and weakness.

The amazing thing is that even with all these problems, we can still know stuff and make progress. But imagine how much more we could know if we managed to build a better system than the one we have. We can do much better. We can change the way the system works.

But I also think we need to change what we think science is, and have different expectations of it. We should expect scientists to be much more open, but also more boring.

The perverse incentive to make research look exciting is at the root of a lot of the problems. Science is not an endless march of exciting, flashy findings. There are transformative discoveries, and we should try and encourage those. But in general, science is incremental and small scale and requires a new kind of intellectual humility. I think we will be much better off when we realise that. ▮

Graham Lawton is a staff writer at *New Scientist*

HOW TO MEASURE THE SPEED OF SOUND

Sound is very slow compared with light. That provides a very low-tech way to measure it, given the right outdoor space.

WHAT DO I NEED?

- a hammer
- a grown-up helper capable of safely wielding the hammer
- a hammer-resistant and preferably resonant surface (a wall, piece of metal or rock will do)
- a stopwatch (or a clock with a second hand)
- a very long measuring tape or a measured ball of string
- a pair of binoculars
- a very large garden or flat open space such as a beach or a park

(Add a metal coat hanger, some s tring and a spoon to check out further properties of sound.)

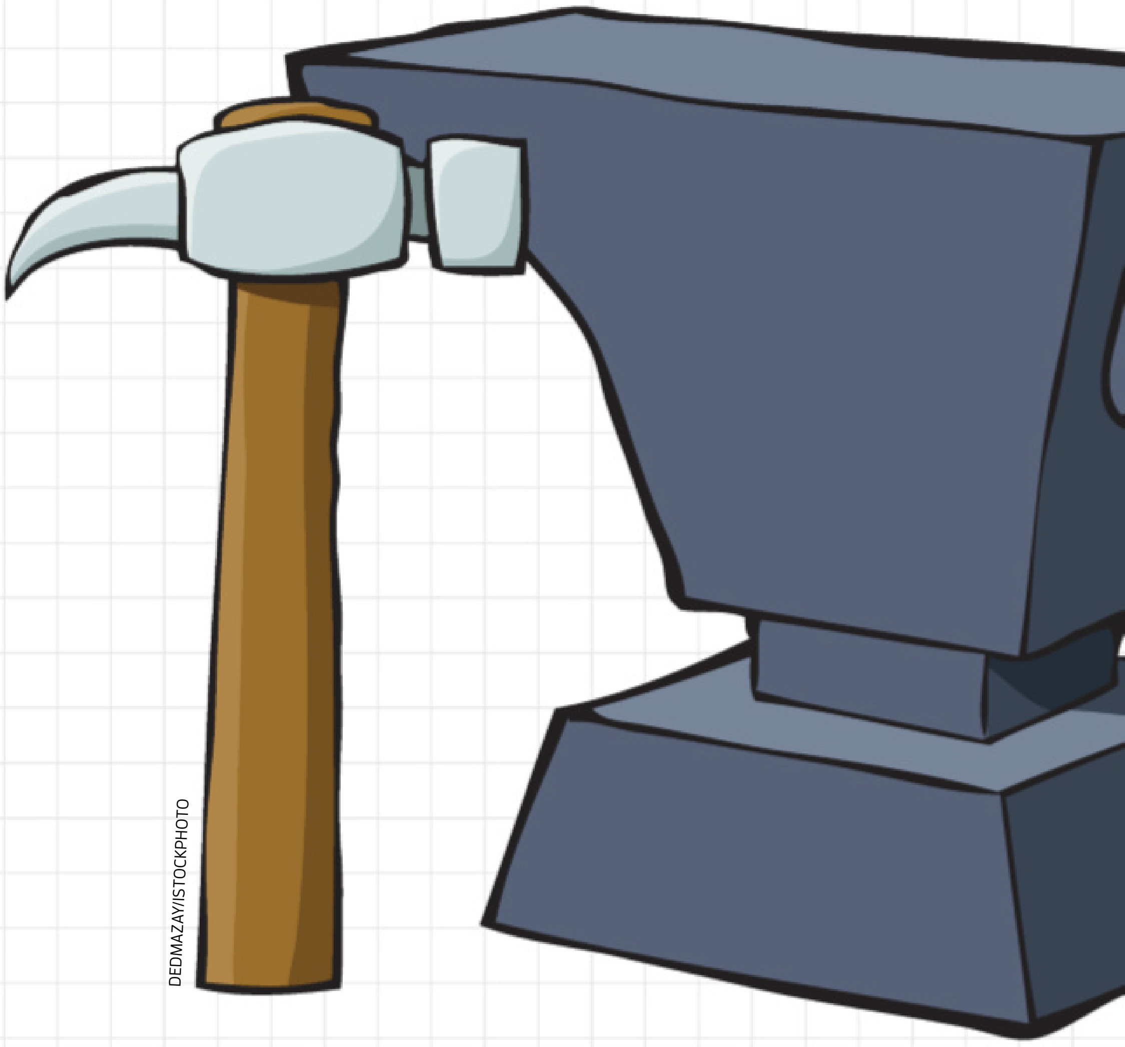
WHAT DO I DO?

It goes without saying that this job must be carried out by an adult because a hammer is used.

Ask your helper to begin striking the hard object once every second with the hammer – they'll need to use the stopwatch and maintain a regular beat. Begin walking away from your helper, looking back from time to time. When you are a few hundred metres apart, use the binoculars if necessary.

WHAT WILL I SEE?

As the distance between you and your helper increases, the delay between them striking the hard object and the sound reaching your ears will become greater. Eventually, the delay will match the time between each beat and the sound will once more appear to coincide with the action of the hammer.



DEDMAZAY/ISTOCKPHOTO

WHAT'S GOING ON?

Sound has a relatively low speed through air, which means you can measure it if you have an open space large enough. Sound travels at 344 m per second in dry air at 20 °C. This may vary at different temperatures, but not by much, so this experiment works pretty well just about anywhere.

When the sound of the hammer once again coincides with the 1 second beat, you are ready to measure the speed of sound. Stop walking away at this point and measure the distance between you and the helper. You should be 344 m away, or very close to that.

Of course, very few of us have such long gardens, and finding a flat, open space of that length, unless you live near a beach, may prove troublesome. Then there will be the problem of outside noises interfering with you detecting the beat of the hammer. If this is the case, ask your helper to increase the frequency of the beats to once every half second (in which case you should find yourself about 172 m from your helper when the beats again coincide with the sound), or once every quarter second if they can (when you'll be about 86 m away).

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WHY DO BOYS HAVE NIPPLES?

Made especially for young and curious minds, *Why Do Boys Have Nipples?* (published as *Where Do Astronauts Put Their Dirty Underwear?* in the US) is based on *New Scientist*'s ever-popular Last Word column, and features 73 other weird questions only science can answer, plus plenty more fun experiments to try at home, too

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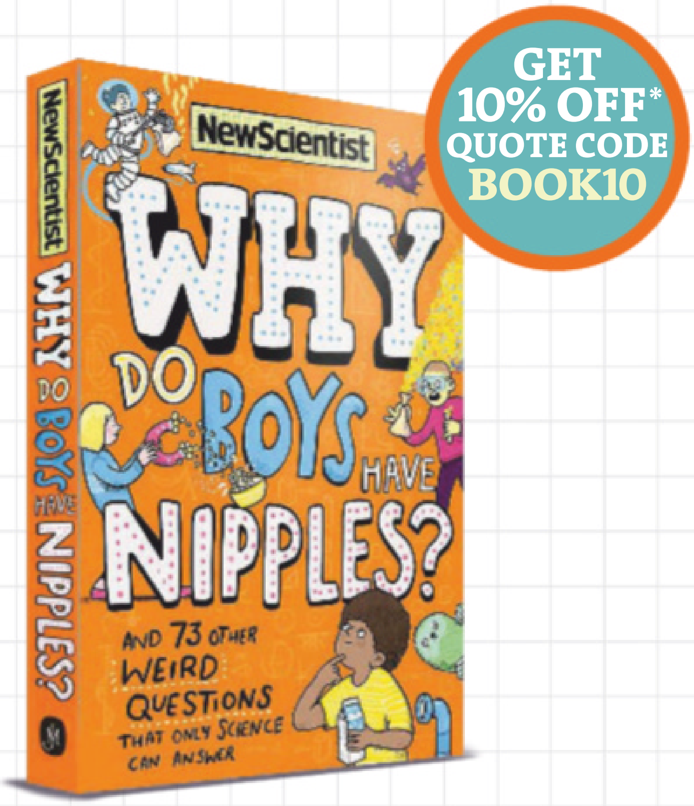
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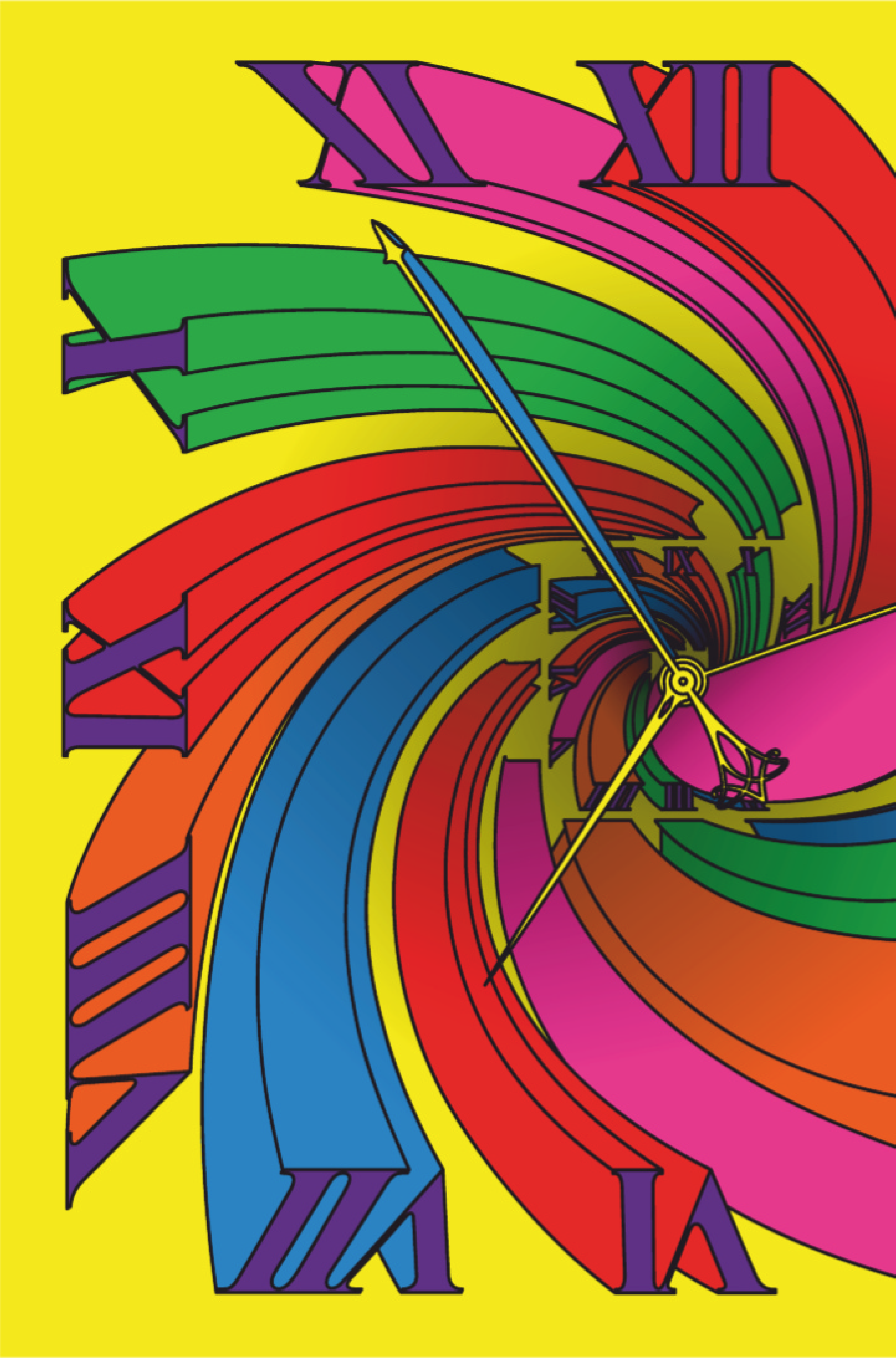

Just a second

The latest atomic clocks are so staggeringly precise that they are going to redefine time. The question now is when, finds **Rachel Nuwer**

ANDREW LUDLOW'S is no ordinary ticker. An intricate tangle of tubes, cables and lasers occupying an entire room at his lab in Boulder, Colorado, it is one of the best timekeeping devices ever made. "It's the Lamborghini of atomic clocks," he says.

That isn't to say it is fast. But Yb-2, as the clock is known, is precision engineered. In fact, it should measure out each passing second so precisely that it wouldn't miss a beat for around 20 billion years – more than the age of the universe.

This is the stunning frontier of precision at which timekeeping now finds itself. Clocks such as Ludlow's could spur on as yet unheard-of technological innovations. They could transform our understanding of the universe, revealing wrinkles in established laws of physics and variations in the fundamental constants of nature that would otherwise be impossible to detect. But for metrologists like Ludlow, they raise an even more fundamental question: is it time once again to redefine time?

EDWARD CARVALHO-MONAGHAN

That might like seem an odd thing to consider for what is a fundamental property of the universe. The flow of time is an enigma; many physicists even suggest it is just an illusion. But clock time is our own invention. We define its basic units – the hours, minutes and seconds that break up the day. They started out as subdivisions of the time it takes Earth to rotate around its axis. Indeed, when astronomer Christiaan Huygens invented the pendulum clock in the 17th century, a second became firmly established as 1/86,400 of a solar day, a factor derived from the division of the day into 24 hours, then 60 minutes per hour and finally 60 seconds per minute.

But Earth isn't a dependable metronome. The duration of its rotation varies by microseconds daily and progressively slows ever so slightly, meaning a second gradually gets longer. That became a problem in the early 20th century, when experimental verification of quantum mechanics and the emergence of radio broadcasting required a steadier, more precise unit of time. It eventually arrived with the microwave atomic clock: a timepiece that ticks in harmony with the frequency of microwave radiation emitted from the rapid oscillations inside caesium atoms, where electrons hop back and forth between closely spaced energy levels.

The first microwave atomic clock was unveiled at the National Physical Laboratory (NPL) in Teddington, UK, in 1955. It was accurate to 1 second every 300 years, meaning two such clocks would fall out of sync by just one second every three centuries. It wasn't long before such precision transformed the way we measure the basic unit of time. In 1967, representatives at the 13th General Conference on Weights and Measures in Paris officially redefined the second as "the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom".

The new second was no longer or shorter than the old one. But the change did provide a much more precise definition of that duration, dramatically improving the extent to which we can be sure each second is the same as the next, and the one after that too.

It is a time standard that persists today, even if the accuracy of microwave atomic clocks has improved to the point that the best caesium clocks now keep time with an accuracy of 1 second in roughly 300 million years. And it is a measure that has served us well. The steady backbeat of the caesium atom's vibration underpins all manner of modern technologies, from GPS and smartphones to the internet and electricity grids, all of which require exquisitely precise synchronisation.

"The current definition of a second is no longer the best we can do"

But it is no longer the best we can do – not by a long way. Ludlow, a physicist at the National Institute of Standards and Technology's (NIST) Physical Measurement Lab, is one of many researchers working on optical atomic clocks, a new generation of timepieces that promise to once again dramatically improve the precision with which we can measure time passing.

We have known for a long time that other atoms oscillate much faster than caesium. Strontium and ytterbium stand out because the electrons surrounding their nuclei have stable excited states, relatively unperturbed by potentially disruptive outside forces like temperature and electric and magnetic fields. The problem was always that their electrons transition between energy levels so fast that there was no easy way to count them.

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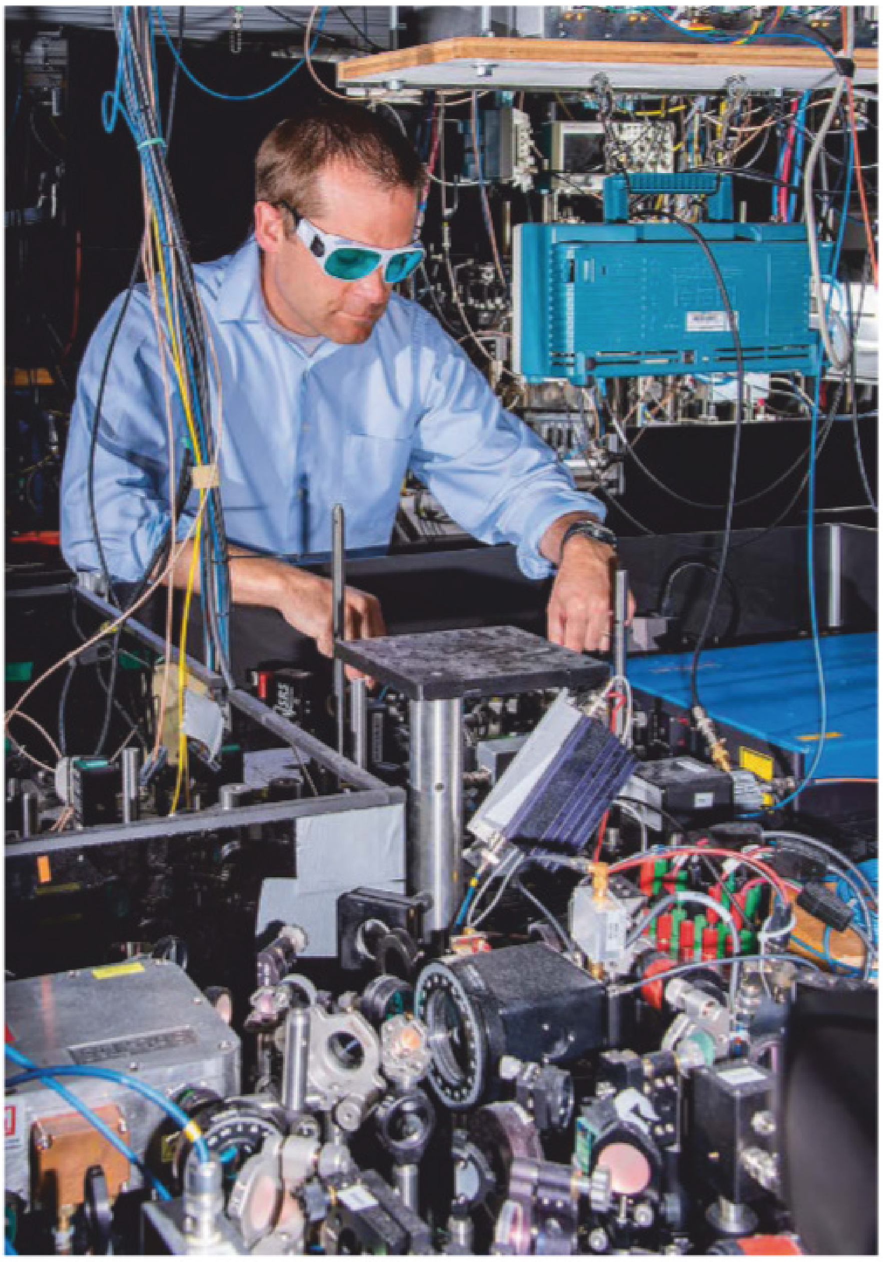
Clocking new physics

A new generation of atomic clocks measure the passage of time so precisely that they will be a boon for fundamental physicists. "These clocks can be used as probes into how the universe works and what it is made of," says Anne Curtis, a metrologist at the National Physical Laboratory in Teddington, UK.

Take dark matter, the elusive stuff thought to hold galaxies together. A network of such clocks here on Earth might help us find it by registering a brief change in the frequency of its atomic oscillations that could indicate its presence. "Everyone has a theory, but with optical clocks we can disprove a bunch of them so people don't waste 20 years of their life," says Curtis.

Now imagine what could be done with optical atomic clocks in space. We could test Albert Einstein's theory of gravity with greater precision than ever before, potentially revealing long-sought deviations that could point to a quantum theory of gravity, uniting quantum mechanics with Einstein's theories. We could even see whether the constants of nature such as the fine-structure constant, which dictates the strength of the electromagnetic interaction between charged particles, have actually changed over the history of the universe.


BURRUS/NIST

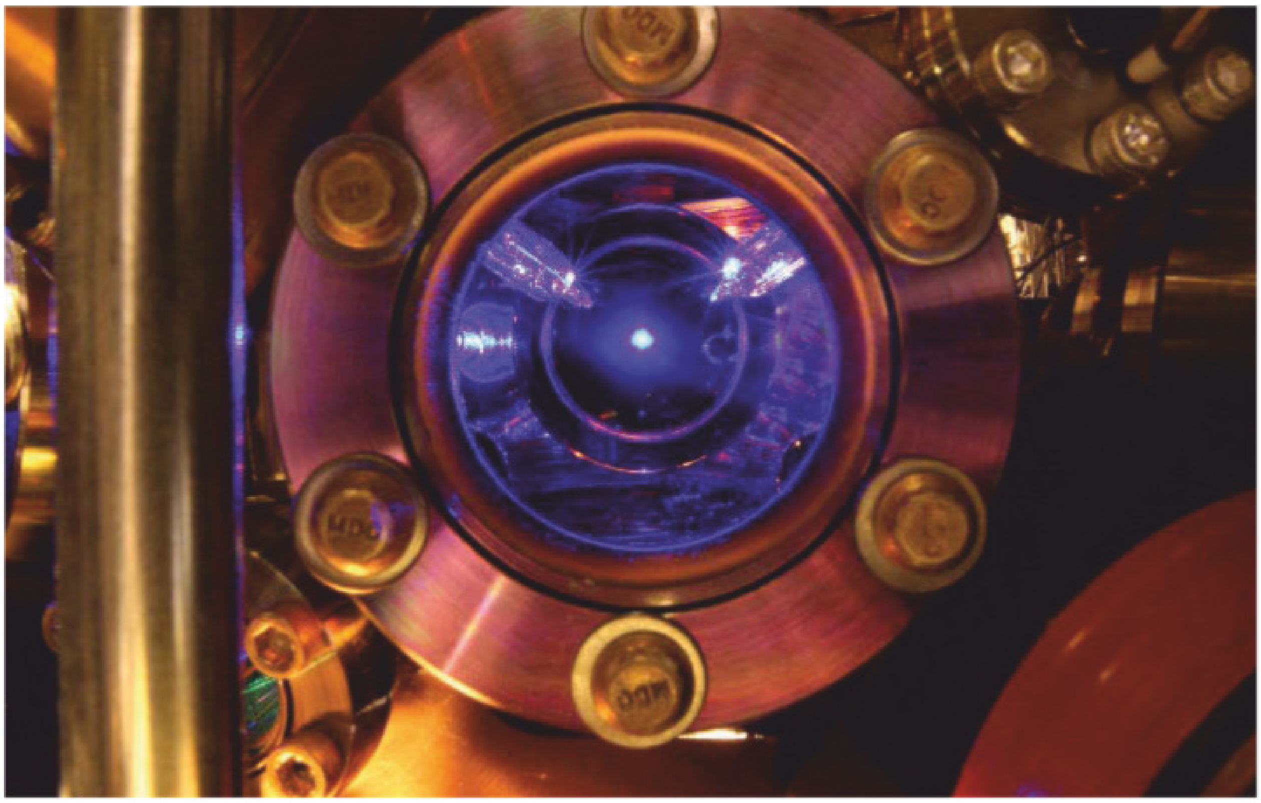
That wrinkle was smoothed out in 1999 with a device called an optical frequency comb, which essentially translates the atomic oscillations measured in the optical range into microwave frequencies. For the first time, the rates at which optical clocks "tick" could be calibrated against one another and the standard set by the caesium atom.

The technique sparked something of an arms race, with labs around the world competing to create ever more precise optical clocks. Currently, top contenders include not only Ludlow's ytterbium clock at NIST, but also a similar device at the RIKEN Quantum Metrology Lab in Tokyo and strontium clocks at NIST and the National Metrology Institute of Germany in Braunschweig.

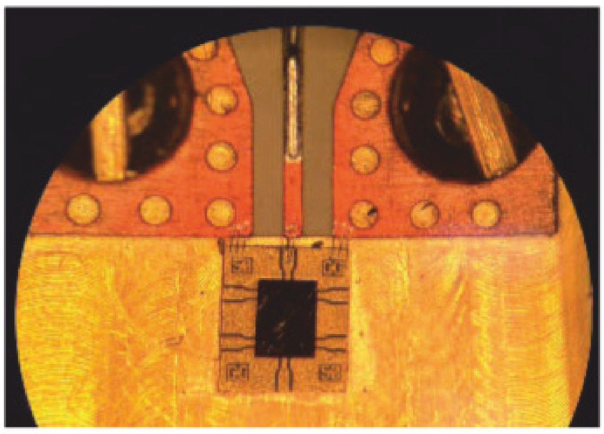
These optical clocks have already achieved a level of certainty nearly two orders of magnitude higher than caesium-based clocks, to the point that most would lose a second only once over the course of the entire history of the universe.

That might seem like overkill. Wrist watches and iPhones don't need to operate to a precision of 18 digits or more. Yet if they can be made sufficiently portable, optical atomic clocks could be used for all sorts of practical purposes, from tracking ice movement to detecting volcanic activity and earthquakes. They are also likely to usher in many technologies and breakthroughs that we haven't thought of yet – and that is before we even get onto the fundamental questions in physics that more accurate timepieces would help resolve (see "Clocking new physics", left).

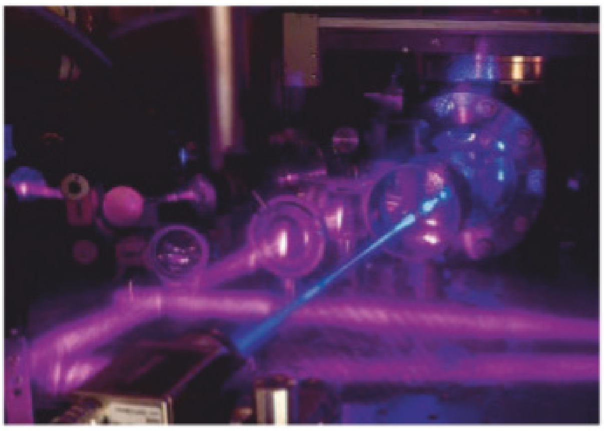
"It's an 'If you make it, they will come' kind of attitude," says Anne Curtis, a metrologist at NPL. "Fifty years ago, when people were contemplating GPS satellites for the first time, no one thought we'd be walking around with handheld computers utilising GPS in real time, just to get to a restaurant."



THE YE GROUP AND BRAD BAXLEY, JILA



F. QUINLAN/NIST



G.E. MARTI/JILA

Opposite page: Andrew Ludlow tends to an optical atomic clock known as Yb-2

Left (clockwise from top): Strontium atoms in a vacuum chamber; a laser that excites the atoms in a different clock; a photodiode that converts optical signals to microwave frequencies

"Frankly, it is awkward to have optical clocks that are 'better' than the very definition of a second"

So what are we waiting for? If optical clocks have already achieved such record-breaking precision, why isn't the world already ticking to their superior beat? "Frankly, it is somewhat awkward to have optical clocks that are 'better' than the very definition of what a second is," says Franklyn Quinlan at NIST. The trouble is that there is a checklist of knotty problems to be addressed before they can establish a new international time standard.

For one thing, you need to pair the signals coming from optical atomic clocks with all the electronic infrastructure already in place, which is currently synchronised using microwave-based clocks. That is tricky because, as well as an optical frequency comb, it requires a separate piece of hardware called an optical-to-electrical converter to transform pulses of light into an electric signal. For a long time, it wasn't clear that it was possible to translate the exquisite timing produced by optical clocks into the microwave frequency range for use in electronics.

But earlier this year, Quinlan, Ludlow and their colleagues cracked the problem. After a decade of work, they finally demonstrated that the translation provided by optical frequency combs yields microwave signals with a 100-fold stability improvement compared with the best microwave atomic clocks. "Considering that it took 20 years of steady improvements to see the last tenfold increase in microwave signal stability, we think a sudden 100-fold increase is a significant advance," says Quinlan.

Curtis agrees. "As part of the roadmap for the redefinition of the second, it is an essential requirement to be able to connect the future optical definition back to the current microwave definition," she says. "This demonstrates this at the highest levels."

Metrologists are now discussing the idea of submitting a proposal to vote on an

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The flow of time is an enigma, but clock time is our own invention

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official redefinition at the next General Conference on Weights and Measures, scheduled for 2026.

To make that happen, the field must first negotiate a few obstacles. For starters, metrologists will have to decide on the cut-off point, a level of precision that everyone agrees is enough for redefinition. "People start getting antsy about how much better do you need to be than the [current] definition before you should redefine it," says Curtis.

Final countdown?

Once that's settled, they will have to thrash out which kind of optical atomic clock should be used to set the official redefinition. There are at least 10 different models being developed in labs around the world, and no single candidate has yet emerged as an obvious best choice.

The clocks differ not only in the types of atoms being used, but also in their architectures. One leading design, the optical lattice clock, measures the oscillations of about 10,000 neutral atoms simultaneously to provide stable, snappy readings. NIST's Yb-2 clock is an example of this. Other candidates include the single-trapped-ion clock, which measures the transition frequency of a single isolated, charged atom in a way that can help to reduce uncertainty. The problem with single-atom clocks is that they deliver a smaller signal than lattice clocks and thus take more time to produce measurements.

"Nature places a fundamental limit on how well we can measure time"

Fritz Riehle, former head of optics at the National Metrology Institute of Germany, says that the diversity in clock designs is a good thing for now, because it provides different possible solutions. But eventually, one must be crowned the winner. This decision will ultimately fall to the board of representatives at the General Conference on Weights and Measures; its conclusion will be based on the recommendation reached by numerous experts, committees, working groups and subgroups. Naming a final winner will probably be more of a human problem than a scientific one, says Riehle, although one he is sure "will be solved in a competitive but respectful way".

Before we get to that point, though, there are still scientific hurdles to clear – not least the verification of the various measurements that the clocks produce. This process ensures consistency and replicability, and it is used to compare optical clocks with each other and the best microwave clocks. Teams in Colorado, France, Germany, the UK, Italy and Japan have already begun using optical fibres to link optical clocks to facilitate such comparisons. But labs still sometimes produce slightly different results, leaving researchers troubleshooting.

According to Curtis, this is all par for the course. "The art and science in metrology is really about assessing all the things that can go wrong," she says. "There's no reason why we can't, over the next five years, all figure out what might be going wrong with our clocks and ensure that it doesn't."

How long a new definition of the second will last is anyone's guess. Just like their microwave-based predecessors, optical atomic clocks will, at some point, be surpassed. In fact, people are already thinking about clocks based on transitions that take place inside the nucleus of an atom, rather than the cloud of electrons that orbit it. "We want to choose something that will last for a long period," says Patrizia Tavella, director of the time department at the International Bureau of Weights and Measures in France. "But we also understand we can't have something that will last forever."

Even future generations of atomic clocks will eventually have to grapple with the nature of time as described by Einstein's general theory of relativity, which predicts that a clock ticks ever so slightly faster for every centimetre it is elevated within Earth's gravitational field. As the precision of our best timepieces reaches into ever more digits, shifts in that field will begin to interfere. At some point, we will run up against "the fundamental limit nature places on us in how well we can measure time", says Jun Ye, another NIST physicist.

It is most likely, then, that a timeless definition of the basic unit of time, just like time itself, will always escape us. ∎

Rachel Nuwer is a science writer based in New York

Feeling queasy?

Motion sickness has tormented us for centuries, but its cause has been a mystery. Now we're finally making sense of this age-old problem, finds **Helen Thomson**

SOMSAK BUMROONGWONG/EYEEM/GETTY IMAGES; NEYRO2008/GETTY IMAGES

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IT STARTS behind your eyes, a niggling ache that heads down towards your stomach where it tumbles and turns before building towards a climax of vomit. Bleurgh! Motion sickness.

This has been a human affliction pretty much since we began travelling on anything but two legs. Most of us have experienced it, and it is likely to become even more prevalent when we all become passengers as driverless cars roll out, space tourism takes off and virtual reality headsets take over, both in the gaming industry and, increasingly, for virtual meetings. Even before covid-19, environmentally conscious businesses had started adopting VR technology to bring international clients together.

Motion sickness is clearly related to the movement of our body and head, but why this results in nausea has been a long-standing mystery. Now, however, evidence from brain imaging and genetics is helping scientists get to the bottom of it – as well as suggesting new ways to solve the problem. It turns out that there is far more to motion sickness than you might think. Your genes, gender and diet all have an influence. It might even come down to your foot size.

The word nausea derives from the Greek for "ship". But motion sickness goes way beyond the odd queasy sailor. Seasickness has had a big impact on history, influencing the outcome of several military conflicts, from the battle of the Red Cliffs, which marked the end of the Han dynasty in ancient China to the defeat of the Spanish Armada by the English in 1588. And, of course, motion sickness isn't confined to the high seas. There are reports of ancient Greeks and Chinese feeling nauseous while being carried aloft in Sedan chairs or travelling by horse and buggy. Their solutions included fasting, drinking the urine of young boys and hiding earth from the kitchen hearth in their hair.

Today, there are more ways to induce motion sickness than ever. One in three of us easily succumb, another third will experience it in rough seas or on a roller-coaster. Nobody is completely immune. We aren't the only species affected, either: cats, dogs, even a variety of birds and fish feel it. In fact, the only animals that don't are those without a vestibular system.

This gives us our first clue as to what the cause might be. The vestibular system is a delicate assemblage of structures within the ear that detects motion (see diagram, page 50). It includes three semicircular canals filled with fluid that sit at right angles to one another. As the fluid sloshes around, the system sends signals about rotational movement to two places. The first is the brain's cerebellum – the region responsible for balance and movement – and the other is the brainstem, which links the brain to the rest of the body and includes areas that trigger nausea and vomiting. The vestibular system also transmits signals to the eyes, which stop the world from blurring as we move our head.

Early ideas about motion sickness put it down to overstimulation of the vestibular system. However, if that were true, why would sailors experience nausea after returning to land? Why don't we suffer motion sickness when jumping around on a dance floor? And why is the driver of a car less likely to feel sick than the passengers?

Attempting to address such anomalies, a second idea posits that motion sickness results from conflict between different kinds of sensory information. When you read in a car, for example, your vision of the book and the dashboard tell your brain that you are stationary, but with all the bumps and turns, your vestibular system is convinced you are moving. These conflicting signals make it difficult for the brain to create a coherent sense of balance, which triggers nausea.

Something unexpected

This "sensory-conflict" idea has problems, too, however. If a novice and a seasoned sailor stand on the same deck, for example, they receive the same sensory signals but have different levels of nausea. There is a third possible explanation for why. Rather than resulting from conflicting signals between your eyes and ears, this idea frames motion sickness as a conflict between these signals and what your brain expects to happen.

This is the idea embraced by Charles Oman

A new idea about motion sickness can explain why car passengers are more likely to feel nauseous than drivers

at the Massachusetts Institute of Technology. In 1990, he argued that when you make a movement, your brain subtracts the actual sensory input from the expected pattern of neural activity, and what's left is a "sensory-motor conflict signal". This is generally small, but it spikes when an unexpected obstacle or motion is encountered, resulting in a corrective response from the brain's motor systems. You then rebalance yourself and the conflict is extinguished. However, if the conflict signal is stimulated over a longer period, it triggers motion sickness.

This would explain why we don't feel nauseous when we jive around a dance floor, but do when we are swayed by high seas. It also explains why sailors get motion sickness on dry land – their sensory expectations don't fit with the stable environment. It even explains the mysterious immunity bestowed on the driver of a vehicle: being in control gives you more accurate expectations of your movements. There was just one problem with Oman's idea – nobody could find evidence for it in the brain. The required network of neurons was missing.

Meanwhile, Thomas Stoffregen, now at the University of Minnesota, had another idea. His research, measuring the subtle movements that people make to maintain their balance at sea, led him to believe that an inability to control our posture is to blame. His studies also indicated a simple solution to motion sickness: when sailors increased the width of their stance, making them more stable, they felt less nauseous.

The debate looked set to continue. Then, Kathleen Cullen, now at Johns Hopkins University in Baltimore, inadvertently discovered Oman's missing neurons. Her team had trained monkeys to move in a specific way to get a treat. Occasionally, the researchers would disrupt this movement – by placing a weight on top of the animal's head, for instance – causing a mismatch between the animal's expected and actual head motion. When this happened, there was a spike in the activity in some neurons in the cerebellum, cells that didn't seem to be active when the animal generated its own ›

"Why don't we experience motion sickness when jumping around on a dance floor?"

Sexist technology

Motion sickness is predicted to become more widespread with increasing use of nausea-inducing VR headsets in gaming and for business meetings. Part of the problem is their size. Bas Rokers at the University of Wisconsin-Madison has found that the lenses on the average VR headset are too far apart to work properly for the eyes of 5 per cent of men and 90 per cent of women, and that this results in greater risk of nausea. "The technology is sexist," says Thomas Stoffregen at the University of Minnesota. "VR can be up to four times more nauseating for women."

Even a perfectly fitting headset can cause queasiness. This needn't be a "necessary evil", says Rokers. The technology could identify when users start to move their head more – a sign that they are starting to feel sick – and pause the game. It is also possible to help people adjust to the cues that make them nauseous by introducing these more slowly.

The easiest solution is to get rid of the most nausea-inducing aspects of an image altogether. Unfortunately, this involves reducing the image contrast. "The irony is that this makes the display worse," says Rokers. "It creates a tension between the engineers who want to make things look as good as possible, and the vision scientists who want to make VR more tolerable for more people."

Ginger stimulates the vagus nerve, which may explain why it can reduce nausea

GETTY IMAGES/DESIGN PICS RF

movement. "It suggests that the cerebellum can perform this amazing computation within a millisecond, in which it compares an internal model of sensory expectation based on prior experience with actual sensory information," says Cullen. Now her team has shown that when an animal subsequently adapts its movement, the internal model is updated and the neurons stop firing.

"I was startled when I saw their work," says Oman. "These neurons arguably play the critical role in motion sickness." But one piece of the puzzle is still missing, he says. Neurons are known to project from this region of the cerebellum to areas of the brainstem that trigger nausea. "It would be a clincher if we could establish that they are the same neurons Cullen's lab has been studying," he says.

Despite this progress in understanding motion sickness, questions remain about why some people are more prone to it than others. Why, for example, do female sailors seem more likely to be affected than male ones? And why do women, especially pregnant women, consistently report more symptoms of motion sickness during VR experiments than men?

One possible explanation for this sex divide rests on a decades-old idea about why motion sickness exists at all. Vomiting is a handy reaction to ingesting bad food, but what is the purpose of being sick in reaction to movement? "Motion sickness is so physically disabling that if there were no positive reason for its presence, natural selection should have acted strongly to eliminate it," says Michel Treisman at the University of Oxford. Such thinking led him to suggest that it is a side effect of our robust reaction to poison: the network involved in keeping us balanced is an ideal early warning system for detecting the unbalancing effects of toxins. Unfortunately, anything else that makes us unbalanced has the same result. If so, it would be beneficial for women to have a lower threshold for motion sickness so that, when they are pregnant, the fetus has increased protection from toxins.

> **"Why do women report more symptoms of motion sickness in VR experiments than men?"**

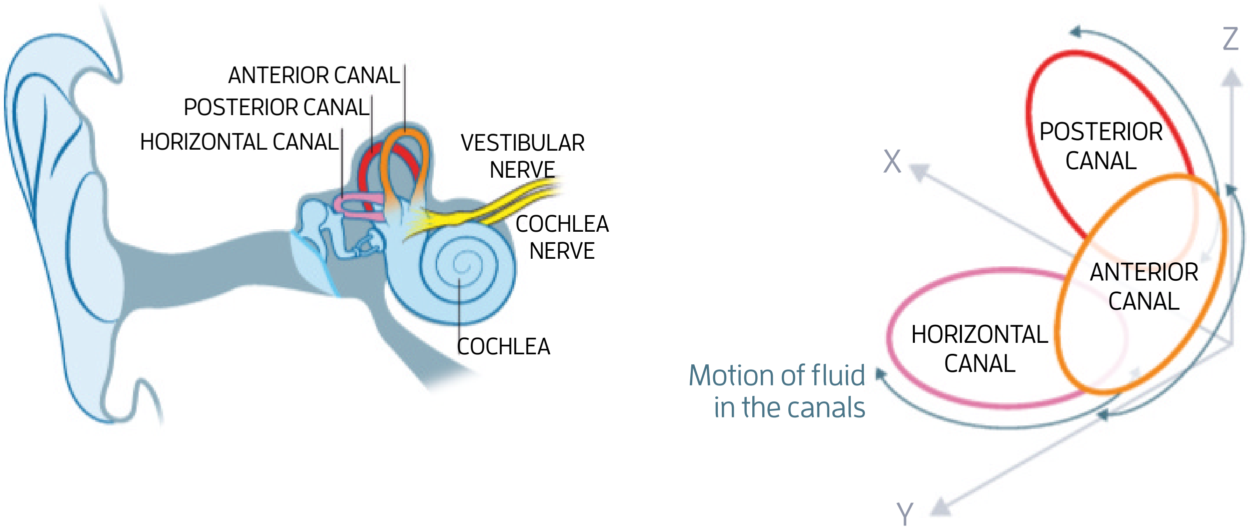
It's in the balance

Stoffregen's research suggests another explanation for why women are more prone to motion sickness than men. "They have different distributions of body mass," he says. "Women carry weight lower in their hips and have smaller feet even when compared with men of similar height." As a result, women may be less physically stable, he says, so find it harder to balance when faced with unexpected movements.

Genes also seem to play a role. In 2015, consumer genetic analysis company 23andMe conducted the first genome-wide study on motion sickness in some 80,000 people and found 35 sections of DNA associated with the condition. The genes involved are related to the development of the eye and ear, and to glucose regulation – women who have particular versions of them are up to three times more prone to motion sickness than men who have them. How the genes influence motion sickness isn't known, but people who experience more motion-induced nausea tend to have lower levels of insulin than those who don't get sick. Because insulin helps us stabilise glucose levels in the body, the researchers suggest

Feeling nauseous?

Fluid-filled semicircular canals in your ear detect your movements but when the signals they send to your brain conflict with expectations, the result can be motion sickness



PIOLA666/GETTY IMAGES

Standing with a wide stance and staring at the horizon are two ways to reduce seasickness

that stabilising glucose through your diet – by eating plenty of vegetables, fruits and whole grains, for example – might help to keep motion sickness at bay.

Closing the case on what causes motion sickness and why some people are more susceptible might lead to new pharmacological targets. Currently, the most effective drug for it is called scopolamine, which works by blocking chemicals that transmit information from the vestibular system to nausea centres in the brain. However, it can cause dry eyes, drowsiness, headaches, palpitations and urinary retention. Antihistamines work too, and probably in a similar way, but they also have side effects.

Regardless of what might be making you susceptible, there are other things you can do to reduce sensory conflict that leads to nausea. Oman recommends staring at the horizon to help synchronise visual information with motion, and keeping your head and body as still as possible to limit unexpected external forces. “Soldiers flying in transport planes found that strapping their head against the seat reduced their sickness,” he says. Habituation training also works. Just as sailors eventually get their sea legs, so prior exposure to the sorts of motion you are likely to experience while travelling can reduce your chances of becoming seasick.

Few other traditional remedies have been tested. “Some people swear by things like pressure bands [worn on the wrist],” says Oman. “There’s no good evidence for them, but any clinician will tell you that placebos can be useful.” There is evidence the placebo effect alone can reduce motion sickness. “When I meet sailors who swear by these things, I say ‘if you believe in it, do it’,” says Oman.

Some ideas do have a little evidence behind them. Studies suggest that ginger can reduce nausea during pregnancy and chemotherapy, and although the jury is out for motion-induced sickness, ginger activates the vagus nerve – which runs between the brain and gut and controls aspects of nausea – and there is evidence that vagal nerve stimulation can reduce motion sickness. Adam Farmer at Queen Mary University of London found this when he fitted volunteers with an epilepsy device called NEMOS – an earphone containing two electrodes that stimulate the vagus nerve as it passes behind the ear. Another way to stimulate the vagus nerve is by breathing slowly and deeply. This simple measure has been found to successfully decrease motion sickness.

The latest idea is a wacky-looking pair of glasses, which are claimed to stop motion sickness in 94 per cent of users. “Seetroën” spectacles, produced by carmaker Citroën, feature four rings – two framing the eyes and one at each side of the head – half-filled with a coloured liquid. “The liquid moves in the same way as the liquid in the inner ear,” says Antoine Jeannin, CEO of Boarding Ring, the company that developed the glasses. “It’s like a visual inner ear, which helps reduce sensory conflict.” Jelte Bos at Vrije University in the Netherlands thinks it is a nice idea. But the glasses only give information about two of the three planes of motion, he adds. “So I’m a little bit sceptical,” he says.

In future, the best solution for motion sickness might not be a pill or ginger or a pair of special glasses. There is a growing realisation that we need to improve the technologies that make us nauseous in the first place (see “Sexist technology”, page 49). “We don’t design the oceans, but we do design VR and driverless cars,” says Stoffregen. “We can’t be held responsible for seasickness, but we are damn well responsible for the technology we create.” ■

Helen Thomson is author of *Unthinkable: An extraordinary journey through the world’s strangest brains*

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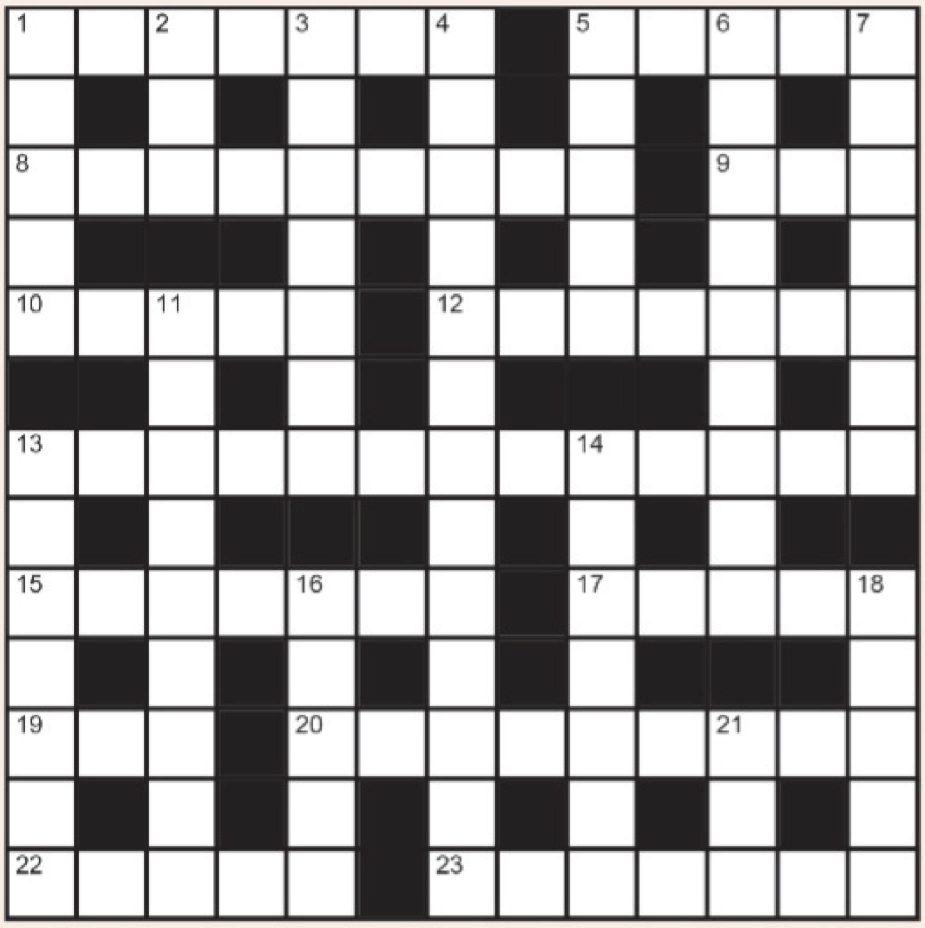
Puzzle
Is Private Perkins facing the right way on parade? p54

Cartoons
Life through the lens of Tom Gauld and Twisteddoodles p54

Feedback
Excel eccentricities and a plague of puns: the week in weird p55

The last word
What is the real stuff in the observable universe? p56

Cryptic crossword #38 *Set by Wingding*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Search around old university library primarily for some charge (7)
5 Spots quantities of chemicals (5)
8 Unexpected melanoma louse concealed (9)
9 Machine part made by elite university briefly (3)
10 Member of religious group is for turning in Curie's city (5)
12 Worn-out Yes CD is losing outer layer (7)
13 US and India invested in calf neuron experiment that could provide lots of energy (7,6)
15 Bird has tail cut off by heartless boy, one with unfaithful partner (7)
17 After 1 December, TV doctor gets degree from Oxford (5)
19 Place of education casually showing some immunity (3)
20 Drinks made by cats catching a small mammal (9)
22 Queen caught fungal disease (5)
23 MDMA is straightforward to get over time in Chicago (7)

DOWN

1 Hold student in temporary accommodation (5)
2 Mysterious phenomenon reported by buffoon regularly (3)
3 Milky white aluminium in state (7)
4 Surprisingly, a boiled badger can be broken down by living organisms (13)
5 Pondered goddess then died (5)
6 Secure economist, a key worker? (9)
7 Scandinavian people with special educational needs making stringed instrument (7)
11 Green industry focusing on green transport (9)
13 Newton misunderstood clue to bat (7)
14 Refreshes high fruit (7)
16 Now, let's get unburdened for young bird (5)
18 Strong leaders of Libyan uprising sent to Yemen (5)
21 Tuber contains no calcium (3)

Quick quiz #65

1 In 1976, research chemist Shashikant Phadnis misunderstood instructions to test a chlorinated compound of sucrose and instead tasted it. What did he then discover?

2 What did an odd bit of "scruff" in her radio telescope read-out lead astronomer Jocelyn Bell Burnell to discover in 1967?

3 The phenomenon of burrs sticking to his clothes inspired George de Mestral to create which material?

4 Which lightweight, superstrong material was invented by DuPont chemist Stephanie Kwolek as her group hunted for a fibre to replace the steel wires used in car tyres?

5 Whose patent count did Shunpei Yamazaki exceed in 2003 to become the most prolific inventor?

Answers on page 54

Quick Crossword #64 *Answers*

ACROSS 1 Arsenide, **5** Parsec, **9** Whiskers, **10** Spooky, **12** R & D, **13** Endorphin, **14** Eiffel, **16** Stannic, **19** Kittens, **21** Twelve, **23** Raindrops, **25** Roger, **26** Indoor, **27** Bursitis, **28** Slinky, **29** Conserve

DOWN 1 Adware, **2** Scientist, **3** Naked, **4** Durrell, **6** Aspartame, **7** Sloth, **8** Cryonics, **11** Odds, **15** Fieldwork, **17** Navigator, **18** Skerries, **20** Smog, **21** Testudo, **22** Wrasse, **24** Indri, **25** Rises

Our crosswords are now solvable online
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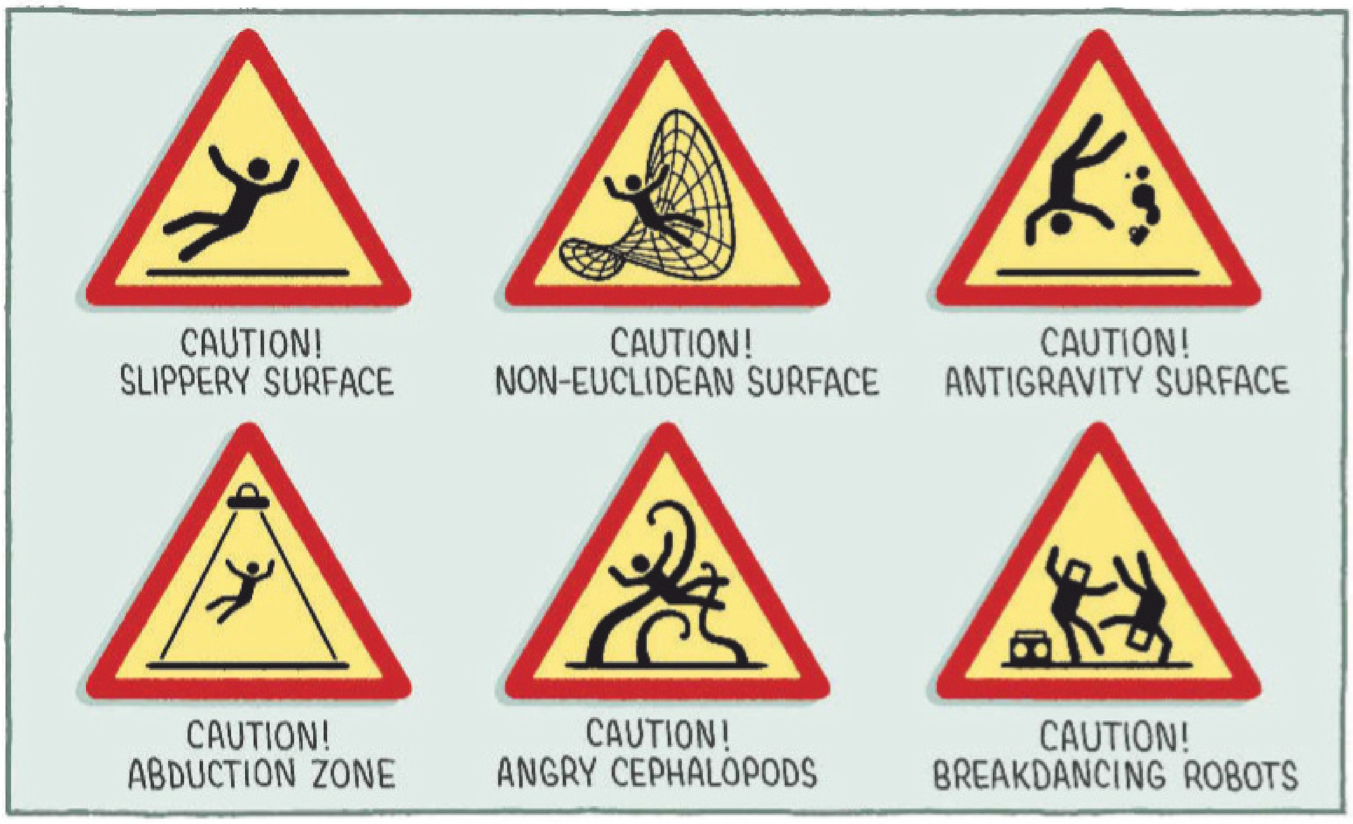
The back pages

Tom Gauld

for New Scientist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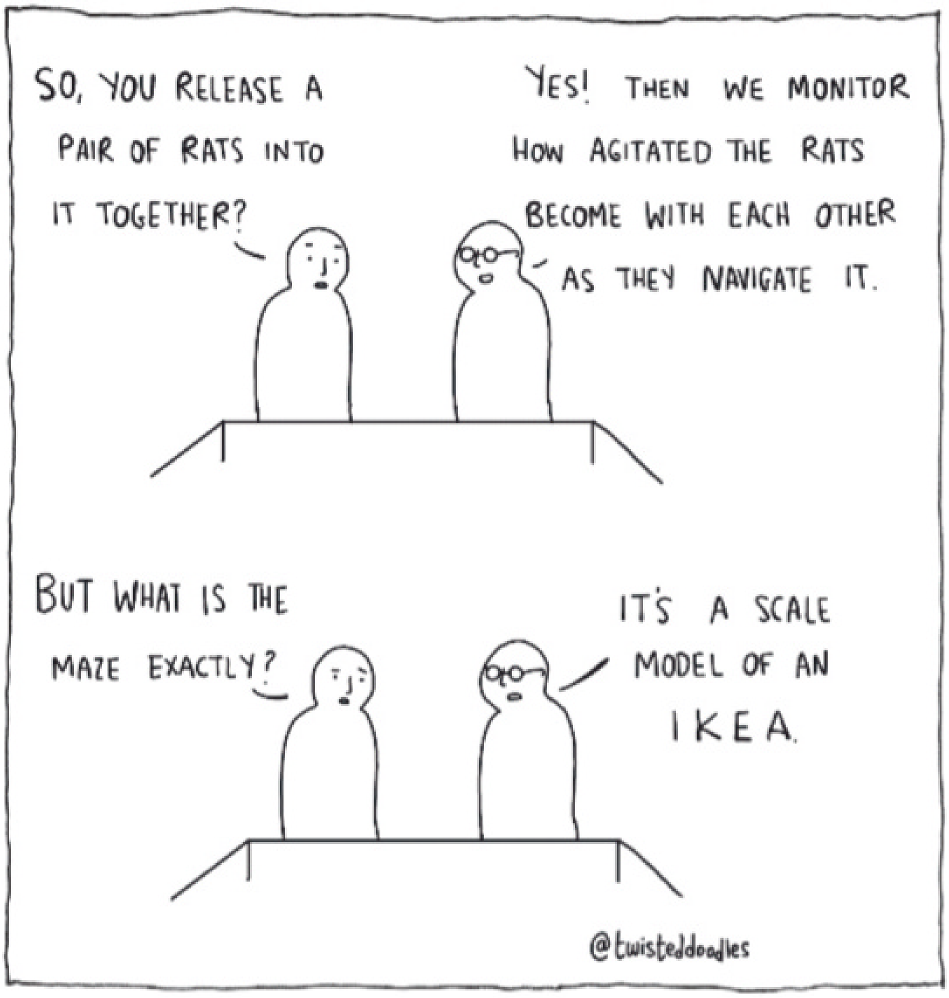
CAUTION!
ANTIGRAVITY SURFACE
CAUTION!
ABDUCTION ZONE
CAUTION!
ANGRY CEPHALOPODS
CAUTION!
BREAKDANCING ROBOTS

Twisteddoodles

for New Scientist


SO, YOU RELEASE A PAIR OF RATS INTO IT TOGETHER?
YES! THEN WE MONITOR HOW AGITATED THE RATS BECOME WITH EACH OTHER AS THEY NAVIGATE IT.
BUT WHAT IS THE MAZE EXACTLY?
IT'S A SCALE MODEL OF AN IKEA.
@twisteddoodles

Quick quiz #65

Answers

1 That it was extraordinarily sweet; it was sucralose, which is now used as an artificial sweetener

2 Pulsars. The scruff was the fast, repeating signals of these rapidly rotating neutron stars

3 Velcro

4 Kevlar

5 Thomas Edison's

Puzzle

set by Rob Eastaway

#73 Changing guard

Fifteen members of the King's 99th Dragoons are standing on parade. "Right turn!" screams the sergeant, and each soldier makes a 90° turn. Unfortunately, many of the squad struggle to know their left from their right. After this manoeuvre, five soldiers end up facing left, including Private Perkins, who is in the middle of the row.

X X X X X X X P X X X X X X X

Any soldier that ends up face to face with another soldier now does a 180° turn. This awkward ritual continues until no soldier can see another soldier's face. Can we be sure that Perkins will end up facing the right way?

Answer next week

#72 A long lane

Solution

Professor Lemma would need to move to number 756.

If Numero's house number is N and Lemma's is L, we are told that $N \times L = k \times (L + N)$, where k is a whole number.

With a bit of rearranging we get: $L = kN \div (N - k)$

We want L to be as large as possible, and therefore $N - k$ must be as small as possible, i.e. $N - k = 1$.

So $k = N - 1$, and hence $L = (N - 1) \times N$.

If $N = 28$, $L = 756$.

Excellent work

Feedback is occasionally reminded of a colleague who, when tasked with collating data in a table, borrowed a ruler and an A3 sheet of paper and returned after a couple of hours with a beautiful hand-drawn spreadsheet.

Why didn't you do it straight in Microsoft Excel, we asked. Well, our colleague informed us, Excel is all well and good for making data look pretty, but what if you want to perform calculations? In those situations, they went on, shaking their head at our naivete, the software is absolutely useless.

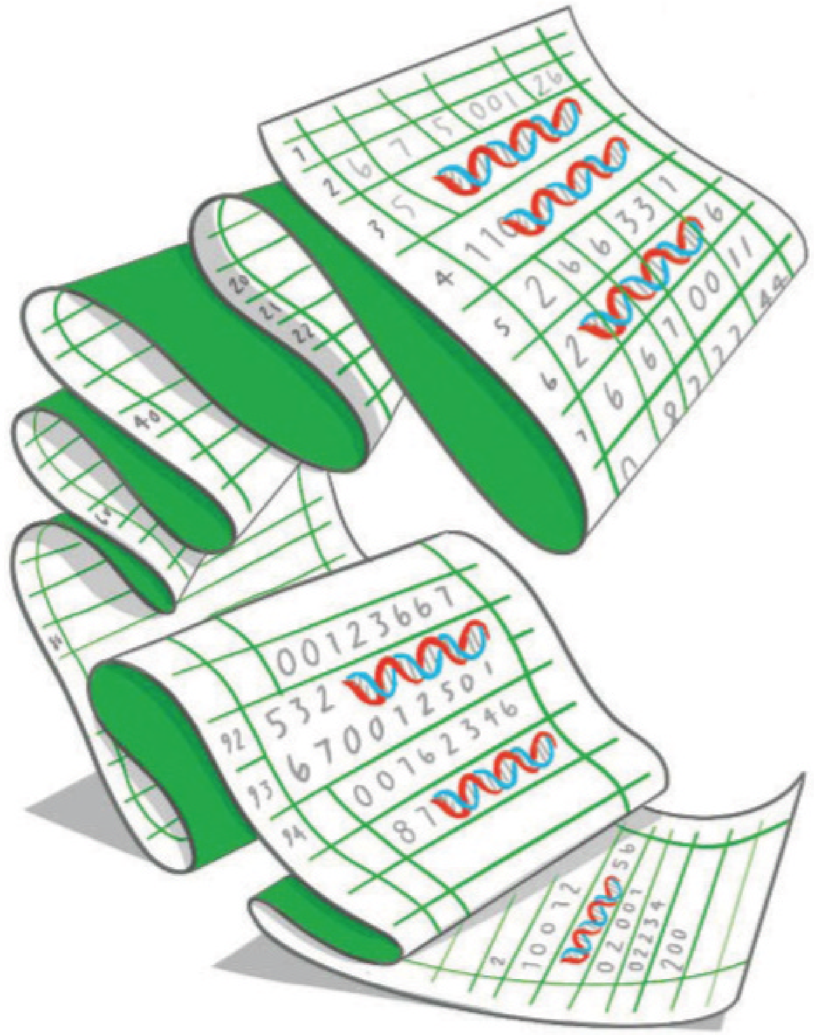
After about six months of long division and half a tonne of printer paper, it turned out that this opinion had been arrived at in error. This same colleague will now happily inform you that, should large-scale data manipulation be your aim, Excel takes some beating.

There are – as all regular Excel users will know – multiple things with which the platform struggles. It is unable to recognise the zero at the start of international phone numbers, for instance, and it is obsessed with rewriting numbers as dates no matter what they actually are.

In recent weeks, however, Feedback has been made aware of another problem with the application. It is one that has never affected us personally, but that has had an entire community of scientists howling in frustration. It turns out that a number of human genes have been given names that Excel automatically converts into dates – take SEPT1, for example, which is involved in maintaining cell shape, as well as MARCH1, which faffs around with certain proteins.

You can imagine just how many data tables have been ruined by the sudden appearance of 01.03.2020 in the middle of a long column of gene names. Hardly bears thinking about. Rather than wait for Microsoft to come up with a solution, though, the HUGO Gene Nomenclature Committee has thankfully taken matters into its own hands.

Henceforward, SEPT1 will be known as SEPTIN1, and MARCH1 becomes MARCHF1. On behalf of geneticists everywhere, we are THRILLED1.



JOSIE FORD

Got a story for Feedback?

Send it to feedback@newscientist.com or
New Scientist, 25 Bedford Street, London WC2E 9ES
Consideration of items sent in the post will be delayed

Pundemic

Another week, another pun in the title of a scientific paper. The offending article this time around comes from *PLoS Pathogens*, and examines the uptick in cases of pertussis, also known as whooping cough.

Feedback will give you till the end of this paragraph to work out what the title might have been. Ready? To make things even easier, you have until the end of the list of authors, which includes Audra Fullen, Kacy Yount, Purnima Dubey and Rajendar Deora.

The answer, of course, was "Whoop! There it is: The surprising resurgence of pertussis". Further examples along these lines are very welcome.

What's in a game?

Those of us who worried that the silly season would pass us by this August, owing to the general un-silliness of the year 2020, have had our fears laid to rest.

It appears that the silly season is not affected by such trivialities as plagues and pandemics. It rises over them. It is too grand and ancient to be stayed in its course by such trifling matters.

There have been silly seasons on this planet every August for millions of years – ever since the first hominin turned to its neighbour and pointed out the monkey on the other side of the river using a melon rind as a hat – and they will be here long after we are gone.

It is in that vein that we bring to your attention a story from the world of the arts. Writer Dana Schwartz recently tweeted about a little investigative reporting one Reddit user had undertaken regarding John Boyne's recent book *A Traveller At the Gates of Wisdom*.

In this sweeping historical novel, they were surprised to find recipes for dyes that involved Octorok eyeballs, red Lizalfos and Hylian Shrooms. Surprised because – as a little light googling revealed – these are all items drawn from the video game world of *The Legend of Zelda: Breath of the wild*.

Octoroks, for example, are octopus-cannon creatures. Lizalfos are a sort of wicked chameleon, and Hylian Shrooms are – well – pretty much what they sound like. What seems to have occurred, Schwartz concluded, was that Boyne had googled how to make a red dye and the first result was from a fictional universe where cephalopods have evolved artillery.

All this would have been speculation of the funniest order if Boyne himself hadn't owned up in a reply to Schwartz's tweet. "Note to self: never talk about poisons in a novel again," he wrote. Feedback respects his decision, but mourns the potential crossovers that might have followed.

Nom d'un nom

In case you missed it, Feedback's latest attempt to make nominative determinism interesting again involves expanding the range of languages and countries from which entries are allowed.

We have already had Finland. Now, courtesy of Adam Feinstein, we get an entry from France. "In case anyone thought nominative determinism was restricted to these shores," writes Adam, "*The Observer* of August 9 quotes a barman in the beautiful French port city of Sète. His name? Eric Bouteille." Many thanks for sending that one in, Adam – do please keep them coming. ▮

Written by Gilead Amit

So much stuff

Just how much stuff is there? Is it possible to estimate the quantity of matter in the observable universe in any meaningful way?

Emily Deibert
University of Toronto, Canada
To understand how much stuff there is in the universe, it helps to first understand what kind of stuff we are talking about. We currently believe that only about 5 per cent of the universe is made up of "ordinary" (or "baryonic") matter, which is things like protons and neutrons – the stuff that you, me, our planet and the stars, for example, are made of. The remaining 95 per cent comprises "dark matter" and "dark energy".

But how do we know that only 5 per cent of the universe is composed of ordinary matter, and how much "stuff" does that actually translate into? One of the ways astronomers have been able to determine the contents of the universe is by observing the cosmic microwave background (CMB). This is like a snapshot of the early universe when it was only about 370,000 years old, and marks the moment when photons, or particles of light, were first able to travel freely throughout the universe.

Today, the remnants of this first light that we see are distributed uniformly across the sky, with very slight fluctuations. It turns out that these fluctuations depend on how much stuff is present in the universe, and what kind of stuff it is. Since light only interacts with the universe's ordinary matter, changing the amount of this type of matter would affect how the light from the CMB appears to us today. We can therefore determine how much of the universe is ordinary matter from the CMB.

There are other ways to measure the same thing, and luckily they all more or less agree with each other. Certain chemical reactions that happened shortly after the big bang depended on the amount of ordinary matter in the universe. If there was more of it present, for example, these chemical reactions would have created more helium, deuterium, lithium, and other elements.

By measuring the ratios of these elements in very old celestial objects, we can get an estimate of how much ordinary matter was present when these reactions occurred. More recently, astronomers have studied the ways in which "fast radio bursts", which are mysterious flashes of radio waves from the distant universe, have interacted with ordinary matter as they travel through the universe. This provides an additional measurement of this stuff.

So how much is there? If you use the methods I described above to figure out the density of ordinary matter in the universe, and you have a good estimate for the volume of the observable universe (about 4 x 10^{80} cubic metres), we get a value of about 10^{80} particles of ordinary matter in the universe. While this may sound like a lot, the universe is so large that when you translate this into a density, you will find that, on average, there is only about one particle of ordinary matter per cubic metre in the universe.

A far greater percentage of the universe is made up of things like dark matter and dark energy, both of which we still don't fully understand.

Mike Follows
Sutton Coldfield, West Midlands, UK
This question is tricky to answer, if not impossible, partly because we don't know the size of the universe or its ultimate fate.

The universe began with the big bang about 13.8 billion years ago. Before 1998, cosmologists expected gravity to slow the resulting expansion of space because galaxies were pulling on each other. According to the prevailing model, if the universe had a critical density, it would eventually stop expanding and become static. A higher density and it would collapse in a big crunch; a smaller density would see it expanding forever.

The critical density is about 10^{-26} kilograms per cubic metre, which is equivalent to about six protons per cubic metre. The estimated volume of the observable universe is 4 x 10^{80} m^3. Mass is the product of density and volume; using the critical density gives a mind-boggling mass of 4 x 10^{54} kilograms of matter of all types in the observable universe.

In the 1990s, most scientists would have bet on a universe with a critical density as this offered a better fit with particle physics and demanded the existence of dark matter, which is inferred from astrophysical observations.

However, all bets were off in 1998, when two research groups independently reported that the expansion of the universe is accelerating. The current consensus is that the universe is composed of a 5 per cent mix of baryonic matter (stuff we are familiar with), 25 per cent dark matter and about 70 per cent dark energy. While it still eludes definitive explanation, dark energy behaves like anti-gravity, repelling masses, instead of attracting them.

In summary, we can work out the mass of the observable universe if we assume its density, but the true size of the universe eludes us. When working out the mass of the universe, should we count energy, given that energy and mass are equivalent? If we exist in a multiverse, then how could we work out what proportion of the total mass belongs to our universe? Perhaps our universe is the only one with baryonic matter. ▮

ELISABETH SCHMITT/GETTY IMAGES

Why does the volume of milk expand so much when it is boiled?

This week's new questions

Spilt milk **Why is it that when you heat milk to a point where it boils, the volume increases and it sometimes spills over?** ***Manyando Milupi,*** *Doncaster, South Yorkshire, UK*

See the light **Why does light reflect in a mirror but go straight through glass?** ***Chris Szymonski,*** *Waupaca, Wisconsin, US*

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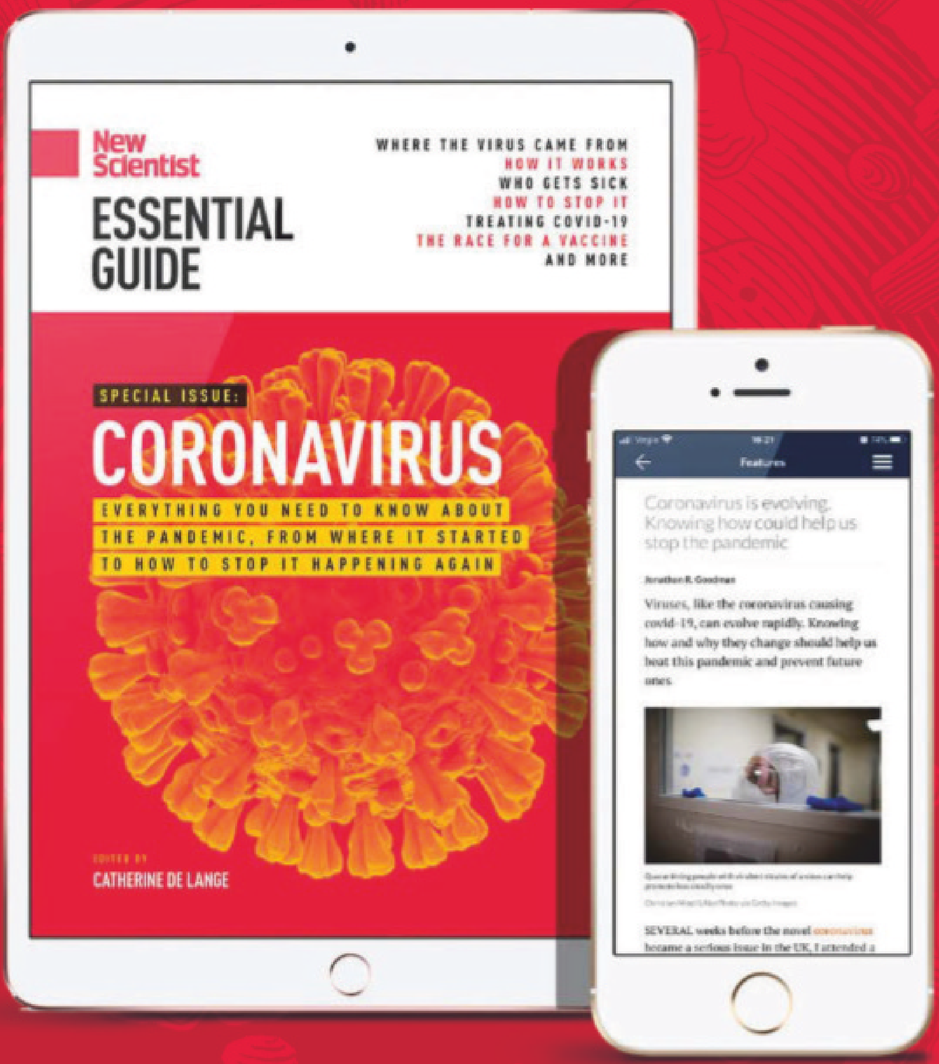
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EDITED BY
CATHERINE DE LANGE
Features
Coronavirus is evolving. Knowing how could help us stop the pandemic
Jonathan R. Goodman
Viruses, like the coronavirus causing covid-19, can evolve rapidly. Knowing how and why they change should help us beat this pandemic and prevent future ones.
SEVERAL weeks before the novel coronavirus became a serious issue in the UK, I attended a

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